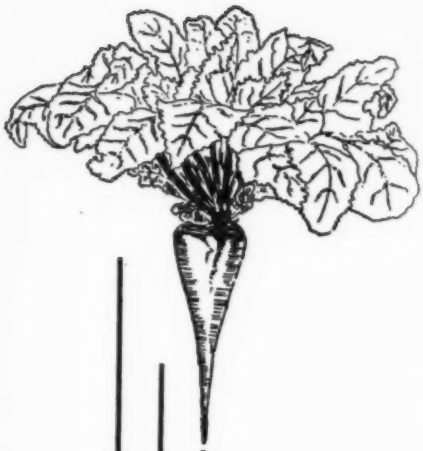

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Left to right: President—Harvey P. H. Johnson, American Crystal Sugar Company, Denver, Colorado; Vice President—Vernal Jensen, The Amalgamated Sugar Company, Ogden, Utah; Secretary-Treasurer—James H. Fischer, Beet Sugar Development Foundation, Fort Collins, Colorado.

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Effects of Climate on Sugar Beets Grown Under Standardized Conditions

ALBERT ULRICH, ET AL.[1]

Received for publication December 17, 1957

The influence of climate on the growth and development of sugar beet plants can be observed in at least three ways: 1. in controlled climate facilities; 2. by growing plants outdoors in pots under standardized conditions; and 3. by a statistical analysis of the climatic and nutritional variables affecting crop growth. Of these methods perhaps the easiest and quite likely the most precise way of studying the effects of climate on sugar beet plants is to grow plants in controlled environments such as in the Phytotron of the Earhart Plant Research Laboratory at Pasadena, California, (12) or in controlled environment chambers now being developed in several parts of the world.

In the Earhart Plant Research Laboratory, the maximum sucrose concentration thus far observed for sugar beets has been approximately 12 percent for plants grown under high levels of nutrition, and 18 percent for plants deficient in nitrogen (6). In both instances, the high sucrose concentrations were observed when night temperatures were maintained at 39° F. Whether these sucrose concentrations are the maximum values attainable in all possible climates of the Phytotron is still unanswered. Certainly by increasing day length, by lowering day temperature or by harvesting plants at different ages (6, 7, 8, 9), the sucrose concentrations of the beet roots high in plant nutrients were not increased appreciably.

The growing of plants in pots under standardized conditions has been used only occasionally as a means of evaluating the effects of climate upon sugar beet plant growth. In one experiment involving an exchange of soils between Berkeley and Woodland, California, the differences in sucrose concentration at Woodland were greater between two successive years than the differences

[1] Kenneth Ohki, University of California, Berkeley, California; David Ririe and F. J. Hills, University of California, Davis, California; R. T. Johnson, Spreckels Sugar Co., Spreckels, California; C. A. Horne, W. A. Lawson, and Duane Darby, Union Sugar Co., Betteravia, California; R. L. Hausenbuiller and W. H. Weaver, Irrigation Experiment Station, Prosser, Washington; Theodore Gessel, The Amalgamated Sugar Co., Nampa, Idaho; C. P. Parrish, The Amalgamated Sugar Co., Twin Falls, Idaho; Jay L. Haddock, Utah State Agricultural College, Logan, Utah; Porter Pederson, and W. E. Larson, A.R.S., U. S. Department of Agriculture and T. S. Aasheim, Huntley Branch Station, Huntley, Montana and J. C. Hide, Montana Agricultural Experiment Station, Bozeman, Montana; C. E. Cormany, Holly Sugar Corp., Sheridan, Wyoming; Bruce L. Baird and Joseph J. Bonnemann, Newell Dry Land Field Station, Newell, So. Dakota; R. R. Allmaras and Lionel Harris, Nebraska Agricultural Experiment Station, Mitchell, Nebraska; R. T. Nelson and R. R. Wood, The Great Western Sugar Co., Longmont, Colo.; Ralph E. Finkner and Roland F. Olson, American Crystal Sugar Co., Rocky Ford, Colorado; Delmar B. Ogden, American Crystal Sugar Co., East Grand Forks, Minnesota; John R. Guttay, Michigan State University, East Lansing, Michigan; Dewey Stewart, Crops Research Division A. R. S., U. S. Department of Agriculture, Beltsville, Maryland.

observed between the two locations in any one year (10). This implies an interaction of climate and location on sucrose concentration operating directly on the plants or indirectly through the soil. Since the plants were grown in soils, climate could have affected soil nutrient supplies, particularly nitrogen, and thus the growth and sucrose concentrations of the beet roots under nitrogen deficient conditions could have been affected differently each year. Such interactions between soils and climates can be minimized by using a very fertile soil or a substrate of inert material, such as vermiculite, and by the daily addition of ample quantities of a complete nutrient solution.

The statistical approach in assessing the importance of climate and nutrition has not been employed extensively thus far to sugar beet growth. Success in this direction, however, will depend upon the kind of information collected and upon the skill of the statistician in unscrambling the various factors associated with plant growth under field conditions. This approach appears to have been employed successfully to the corn plant recently (4) and perhaps if similar kinds of information are collected for the sugar beet plant the climatic factors of temperature relative to soil and air, day length, light intensity, rainfall and mineral nutrition can be correctly integrated.

The natural outgrowth of the controlled environment experiments conducted in the Phytotron (6, 7, 9) is the growing of plants under standardized conditions in areas where sugar beets are grown commercially in the United States. This was done during 1954 at 17 locations in cooperation with the member companies of the Beet Sugar Development Foundation, the United States Department of Agriculture and the various agricultural colleges throughout the United States. In carrying out this study, the technique adopted involved the use of vermiculite as the substrate, a complete nutrient solution as the source of nutrients and water, and a single standard beet variety, which was planted on the same day and harvested exactly five and one-half months later at all locations. In this way, the effects of climatic factors and not that of the soil or of the cultural practices were observed.

It is the purpose of this paper to report the effects of climate on the sucrose concentrations of the beet root and on the growth of crowns, roots, leaf blades, and total tops as observed at these locations in 1954.

Methods and Procedures

A complete set of instructions was prepared and distributed to each cooperator as listed in the footnote on page 1. At each

of the 17 locations there were ten replications of four treatments: A, Standard variety with local planting and harvesting dates; B, local variety with local planting and harvesting dates; C, standard variety with standard planting and harvesting dates; and D, local variety with standard planting and harvesting dates. Treatments A, B, C and D were assigned at random in groups of four pots to a block making up a replication. Altogether there were ten blocks or a total of forty pots to a location. At most locations the pots were placed in two parallel rows with five blocks to a row. The plants in Treatments A and B were planted and harvested on dates common to the locality, whereas those in Treatments C and D were planted on May 1, 1954 and harvested on October 15, 1954.

The pots for each location, except at Beltsville, were reclaimed frozen egg cans 10 inches in diameter and 12 inches deep, and had a capacity of four gallons per pot. Drainage was provided by punching four small holes spaced equidistant on the sides of the container near the bottom of the pot. The containers were protected on the inside by a sanitary lacquer, and as a rule, were coated on the outside with aluminum paint. At Beltsville, the pots were of glazed earthenware and had a capacity of 3 gallons. Vermiculite was added in small increments directly from the sack into the pots in rotation until the pots were filled. Thereafter, the vermiculite was packed uniformly by dropping each pot briskly on a hard surface five times. The pots were filled again to capacity and then watered with nutrient solution until the solution began to drain 10 to 15 minutes later. Forty such pots were placed in two rows with a 20-inch spacing between pots. At all locations except Betteravia, the pots were surrounded by soil within a boxed area on top of the soil surface or buried directly in the soil at soil level depth.

Seeds of the variety S.P. 53104-0 were furnished by Dewey Stewart, USDA, Beltsville, Maryland. These were used as the standard variety for each location. The seeds for the local variety were those normally planted in the locality. All seeds were pretreated with Phygon XL, 1 percent by weight, prior to planting. At planting, twenty seedballs per pot were placed equidistantly on the vermiculite in a circle having a diameter of 5 inches. The seedballs were planted at a depth of ¾-inch and were watered lightly immediately thereafter with nutrient solution.

The nutrient solution used was a modified Hoagland's nutrient solution I added at ½ strength (2). It contained the usual salts plus sodium chloride at a concentration of 0.0005 M. Sodium chloride was added because chlorine has been shown to be

essential for sugar beet plants (11) and sodium has often been thought to be needed for growth. Iron was added as FeEDTA Na_2 complex (3). To simplify the preparation of the nutrient solution, four stock solutions were prepared as outlined in Table 1.

Table 1.—Composition of Stock Solutions.

Solution Number	Material	Weight in Grams
1	Potassium phosphate (KH_2PO_4), monobasic (Technical grade)	270
	Potassium nitrate (KNO_3) (Technical or fertilizer grade)	1000
	Magnesium sulfate ($MGSO_4 \cdot 7H_2O$) (Epsom salts, U.S.P.)	1000
	Sodium chloride (NaCl) (Non-iodized table salt)	120
	Stock solution No. 4—one pint. (See below) (make up to 4¾ gallons—use one quart for 55 gallons)	
2	Calcium nitrate ($Ca(NO_3)_2 \cdot 4H_2O$) (Technical or fertilizer grade) (make up to 4¾ gallons—use one pint per 55 gallons)	4250
3	Sequestrene NA2	140
	Ferrous sulfate ($FeSO_4 \cdot 7H_2O$) (Technical or fertilizer grade) (make up to 4¾ gallons—use one quart for 55 gallons)	95
4	Boric acid (H_3BO_3), crystal	45.8
	Manganous sulfate, monohydrate powder ($MnSO_4 \cdot H_2O$)	24.6
	Zinc sulfate ($ZnSO_4 \cdot 7H_2O$), crystal	3.5
	Cupric sulfate ($CuSO_4 \cdot 5H_2O$), crystal	1.3
	Acid Molybdic ($MoO_3 \cdot 2H_2O$), assay 85% MoO_3 (make up to one gallon—use one pint for Solution No. 1)	0.28

The final nutrient solution contained the following salts, expressed as millimols per liter: 0.5 KH_2PO_4, 2.5 KNO_3, 1.0 $MgSO_4$, 0.5 NaCl and 2.5 $Ca(NO_3)_2$. The microelements, expressed as milligrams per liter, were present as follows: 0.25 B, 0.25 Mn, 0.025 Zn, 0.01 Cu, 0.005 Mo and 2.5 Fe.

A 55-gallon oil drum, either unpainted or painted with Amercoat No. 35, served as the tank for nutrient storage. The tank was filled to the half-way mark with tap water and the following amounts of the stock solutions were added: 1 quart solution No. 1; 1 pint solution No. 2; and ¼ pint solution No. 3. While stirring, the tank was filled with tap water.

The plants were watered daily with nutrient solution and in some locations, twice daily, depending upon the climatic conditions. At each watering, an excess of solution was added, which drained off shortly thereafter. In this way, the proper salt concentrations were maintained in the nutrient solution at all times.

The plants were thinned at three different stages of growth. The first thinning took place when the plants were at the two-leaf stage. At this time the plants were thinned to one seedling per seedball. In the second thinning, the plants were at the 4-leaf stage. These were thinned to 4 well-spaced plants per pot. In the final thinning, when the plants were in the 6- to 8-leaf stage, they were thinned to 2 plants per pot. At all locations, a uniform stand of plants was obtained by thinning out the very small plants and the exceptionally large ones, leaving the best uniform plants for the growth study. At some locations, a special screen was constructed to protect the plants against mechanical injury from hail storms. Such damage was minimized in the thinning process by removing the injured plants.

During the growing season daily maximum and minimum air temperatures were recorded for each station. Records were obtained by means of automatic temperature recorders, maximum and minimum thermometers and from the U. S. Weather Bureau reports.

At the time of harvest, the tops were separated from the beet roots at the upper leaf scar and records were taken from the tops and roots as follows: (a) Total fresh weight of the tops; (b) the number and the fresh and dry weights of leaf blades more than 1 inch in width; (c) fresh and dry weights of remaining unclassified material; (d) number and dry weights of the old leaves removed per pot; (e) the height of the tallest recently matured leaf in each pot of plants; (f) total weight of the individual roots plus crown; (g) weight of the crown (portion between upper and lower leaf scars); and (h) weight of storage root (without the crown). The fresh material of the tops was dried at 70 to 80° C. Pulp from individual roots (exclusive of crown) was prepared with a Kiel rasp and analyzed for sucrose in duplicate by the methods recommended by Browne and Zerban (1).

Results

The results presented in Tables 2 through 6 have been arranged so that the treatment means can be compared locally on an absolute basis and nationally on a relative basis using the national average for Treatment C as 100 percent. The significance of a treatment mean within a location can be assessed by the least significant difference (LSD) at the 5 percent level and by the F values for the date and variety effects and for the date-variety interactions at each location. The relative values in terms of Treatment C make it possible to compare the local results either on a local or national basis. The local mean is an average for all treatments at that location. The coefficients of variability

give a measure of variation for the location; the smaller the value, the greater the precision of the measurement.

Sucrose concentrations: The sucrose concentrations for the beets in the standard variety planted and harvested at the standard times (Table 2, Treatment C) ranged in value from 9.0 to 15.2 percent. None of the values is lower than the value of 7.2 to 9.2 observed in the Phytotron during the simulated warm days and nights but many of the values are much higher than the 12 percent maximum found in the high nutrient plants grown at low night temperatures (6, 8, 9). For example, the highest value in Treatment C, 15.2 percent, was observed at Twin Falls, Idaho, and Logan, Utah, and a still higher value, 16.3 percent, was observed for the local variety at the standard planting and harvesting dates, Treatment D, at Twin Falls, Idaho. (Table 2). Neither the local variety nor the standard variety at the local planting and harvesting dates (Treatments A and B) exceeded this figure.

The local variety at all locations tended to exceed the standard variety in sucrose concentration. On a national basis, the local varieties averaged approximately 0.4 percentage units more than the standard variety regardless of the planting and harvesting dates. At some locations, for example, at Twin Falls, Longmont, Rocky Ford, and Beltsville, the local variety exceeded the standard variety by an average of 1.6 percentage points. In the remaining locations, the local variety was about the same in sucrose concentration but certainly not significantly lower than the standard variety.

The planting and/or harvest date had a significant effect upon the sucrose concentration of the beet roots in 7 out of the 17 locations (Table 2). In 4 of the 7 locations, the increases were in favor of the standard dates and not for the local dates. However, this does not mean that the standard dates are actually better than the "local dates" because at some locations, e.g. Mitchell, Nebraska, the standard dates were in reality the local dates. When only the local planting date differed from the standard dates as in Berkeley, Davis, Spreckels, Prosser, Twin Falls, Logan, Rocky Ford, and Grand Forks, the significant F values for date observed at Spreckels and Prosser (Table 2) imply that the effects of the early planting dates on the plants carried over to the time of harvest, October 15. This effect is at variance with the results obtained in the Phytotron where the variations in climate ten weeks prior to harvest had no significant effect on the sucrose concentration of the beet roots (9).

Apparently, by planting beets in March the standard vari-

Table 2.—Sugar Beet Climate Study, 1954, Percent Sucrose.

Location	Local Var.*	Local Dates**	Mean Values*** A (Local Dates) SP*	A (Local Dates) LV*	B (5/1-10/15) SP*	B (5/1-10/15) LV*	LSD 5%	F Values[1] Date	F Values[1] Variety	F Values[1] DxV	Relative Values[2] A	Relative Values[2] B	Relative Values[2] C	Relative Values[2] D	Local Mean	C.V.
Berkeley, Calif.	US75	3/1-10/15	13.2	14.0	14.3	13.8	0.8	0.31	2.21	5.01	107	113	116	111	13.8	6.4
Davis, Calif.	US75	3/1-10/15	10.3	10.9	11.8	11.2	n.s.	3.99	0.01	1.61	83	88	95	90	11.0	13.3
Spreckles, Calif.	US75	3/1-10/15	9.6	10.3	12.6	12.1	1.7	15.72	0.04	0.92	78	83	102	98	11.2	17.1
Betteravia, Calif.	US75	2/18-9/1	13.6	12.8	14.0	14.1	1.0	5.40	0.91	1.54	110	103	113	114	13.6	8.1
Prosser, Wash.	028	3/16-10/14	13.5	13.8	14.7	15.2	0.7	26.31	2.22	1.24	109	111	119	123	14.3	5.2
Nampa, Idaho	US22/3	4/6-10/3	11.1	10.8	11.5	11.7	n.s.	0.73	0.01	0.15	90	87	93	95	11.3	19.7
Twin Falls, Ida.	US22/3	4/15-10/16	15.8	15.9	15.2	16.3	0.6	0.05	8.31	7.64	128	128	123	132	15.8	3.9
Logan, Utah	828	4/26-10/15	15.1	15.5	15.2	14.5	n.s.	2.35	0.17	3.32	122	125	123	117	15.1	6.5
Huntley, Mont.	GW359	4/14-10/5	11.2	12.0	13.4	12.4	1.0	13.38	0.07	5.74	90	97	108	100	12.3	9.0
Sheridan, Wyo.	MW391	5/10-10/5	10.9	10.9	11.6	12.1	1.1	5.94	0.45	0.55	88	88	94	98	11.4	10.9
Newell, S.D.	828	4/20-10/1	8.9	9.0	9.0	10.5	n.s.	1.29	1.35	1.22	72	73	73	85	9.3	22.6
Mitchell, Neb.	GW359	4/15-10/2	9.7	10.4	10.6	11.4	1.2	4.53	3.05	0.30	78	84	86	92	10.5	12.5
Longmont, Colo.	GW359	4/7-10/22	10.5	11.3	9.2	11.1	1.5	1.95	5.92	1.07	85	91	74	90	10.5	15.9
Rocky Ford, Colo.	Am 1	4/22-10/13	11.3	13.2	11.1	12.8	1.4	0.36	12.43	0.01	91	107	90	103	12.1	13.1
E. G. Forks, Minn.	Am 3	5/1-10/15	14.1	14.0	13.5	14.1	n.s.	0.38	0.26	0.51	114	113	109	114	13.9	9.5
E. Lansing, Mich.	53AB3	4/15-10/28	14.1	13.4	13.0	12.6	0.8	10.88	2.89	0.19	114	108	105	102	13.3	6.9
Beltsville, Md.	201-B	4/19-11/15	9.6	12.3	10.4	12.1	1.3	0.50	23.82	1.08	78	99	84	98	11.1	12.9
National Means		5/1-10/15	11.92	12.37	12.38	12.79	—	—	—	—	96	100	100	103	—	—

*The national variety, SP53104-0 is a curly top leaf-spot resistant selection and was supplied by Mr. Dewey Stewart, U.S.D.A., Beltsville, Maryland.
LV = Local Variety.
**Local planting and harvesting dates.
[1] Required F values for the 5%, 1% and 0.1% levels are 4.21, 7.68 and 13.6, respectively.
[2] Relative values are expressed as percent of national mean for treatment "C."
CV = Coefficient of variability.
LSD = Least significant difference.
***A = SP53104-0, local dates; B = local variety, local dates; C = SP53104-0, May 1-Oct. 15; D = local variety, May 1-Oct. 15.

ety was induced to bolt at Berkeley and at Spreckels (Treatment A) and this accounts for the significant date and variety interaction at Berkeley and the date effect observed at Spreckels. At Prosser, however, bolting was not a problem, but instead the difference in actual harvest time of 3 to 4 days between the A and B treatments (October 14) and the C and D treatments (October 17-18) may have produced the difference in sucrose concentrations of the beet roots. The cause for the significant effect of planting date at Spreckels for the local variety is unknown, since bolting was not a problem for the U.S. 75 variety there. At Huntley, Montana, and East Lansing, Michigan, the significant date effects can be attributed to the local harvest dates which differed appreciably from October 15, 1954.

The significant date-variety interactions observed at three locations, Berkeley, Twin Falls, and Huntley, are readily understandable for Berkeley, where the early planted beets in Treatment A bolted, but for Twin Falls and Huntley, the causes for the significant interactions are unknown. At Twin Falls the interaction is mainly attributable to the drop in sucrose concentration for Treatment C (rise in sucrose concentration in Treatment A) and at Huntley the interaction is again associated with Treatments A and C (Table 2).

On a national basis the sugar concentrations of the beet roots followed several interesting patterns, although admittedly the results are not at all completely understandable. In California, the highest sugar concentrations were observed at Berkeley and Betteravia and the lowest at Davis. The low figures at Davis are most likely associated with the warmer climate of the inland area as contrasted with the coastal climates of Berkeley, Spreckels, and Betteravia. However, the relatively low values observed at Spreckels do not fit into this picture. In a similar series of locations starting from Prosser and continuing through to Nampa, Twin Falls, and Logan, all sugar concentrations were well above the national average except for Nampa. What caused the distinctly lower sugar concentrations at Nampa was not revealed from a study of the temperature records or through a personal inspection of the plants on July 29 and 30, 1954. The relatively low sugar values at Huntley, Sheridan, Newell, Mitchell, Rocky Ford, and Longmont can only be explained at Longmont where a spider mite infestation could have reduced the sugar concentrations of the beet roots, otherwise, for the climatic area, all sugar values should have been high. At Beltsville, the low values may have been caused by the warm nights just preceding the harvest on October 15, but this explanation does not hold for the November 15 harvest for the standard variety.

Sucrose concentrations in relation to heat sums: Even though the primary purpose of the sugar beet climate study was to observe the effects of climate on the sugar concentrations and to note the size of the roots and tops, there was also the hope that these values might be related to the maximum and minimum temperatures recorded at each location. Because of the close relationship of night temperature to the sugar concentration found experimentally in the Phytotron (6, 8), various comparisons of minimum night temperature to sucrose concentrations were made. Minimum temperatures summed as degree days above 32° F. for one- two- three and four-week intervals prior to harvest were plotted against sucrose concentrations for beets in the C Treatment. None of these comparisons gave significant correlation or regression coefficients, although the data plotted each time for the period gave a most interesting pattern as is illustrated in Figure 1 for the four-week interval.

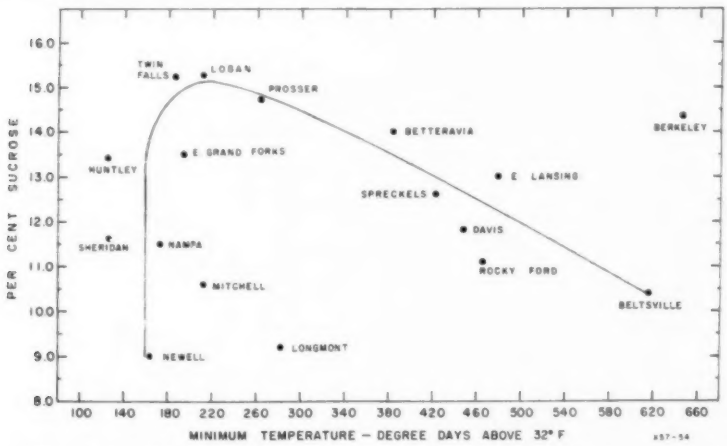

Figure 1.—Relationship of sucrose concentration to minimum night temperatures above 32° F. summed for four weeks prior to harvest. The sucrose values are means of 10 replications of the standard variety SP53104-0 planted May 1 and harvested October 15, 1954 (Treatment C).

Conceivably, the pattern presented in Figure 1 may be entirely fortuitous, but more likely the results are related to two or more variables, one being minimum night temperature and the other light. The part of the curve primarily associated with night temperature starts at the apex, with Twin Falls, Idaho, and Logan, Utah, and ends with Beltsville, Maryland. (Figure 1.) One glaring exception to this orderly decrease in sucrose concentration with increase in heat sums is the point for Berkeley,

California. Even though the night temperatures prior to October 15 were warm, the sucrose concentrations for Berkeley were high —a phenomenon which might have been related to better light conditions prevailing for four weeks prior to harvest. While actual light measurements were not made at the time, warm weather in Berkeley is nearly always accompanied by good light, i.e., an absence of high cooling fogs.

The failure to attain high sucrose concentrations at the Sheridan, Nampa, Mitchell, Newell, and Longmont locations, in spite of the low minimum night temperatures, may have been due to poor light or to some factor as yet unknown. At Longmont, it is possible that the low sucrose concentrations observed there may have been due to a spider mite infestation as stated earlier.

Contrary to expectations, sucrose concentrations were not related to latitude as observed for top growth. The correlation-coefficient of +0.062 is a value statistically nonsignificant.

Total beet root weights (roots plus crowns): The results for the beet root weights for all locations are given in Table 3. As one might expect there is a far wider range of values for root weight than for sucrose concentrations. On an absolute basis, the weights ranged from 940 to 3331 grams per pot for the standard conditions (Treatment C) and 990 to 4664 for the standard variety but for the local planting and harvesting dates (Treatment A). Still lower and higher values were observed for the local variety at local planting and harvesting dates in Treatment B. Outstanding effects of the local planting and harvesting dates (Treatments A and B vs. C and D) were observed at Davis, Betteravia, East Lansing, and Beltsville and to a lesser extent at Berkeley and Spreckels. In all instances, except for Betteravia where the early planted beets were damaged by frost, the local dates increased beet growth greatly.

Significant variety effects were observed at Spreckels, Betteravia, Twin Falls, Huntley, Sheridan, Mitchell, Longmont, Rocky Ford, East Lansing, and Beltsville. In every case, except at Rocky Ford, where an unusual occurrence of curly top disease decreased growth, the local variety produced larger beet roots than the standard variety, S.P. 53104-0. Outstanding increases in favor of the local variety were observed for GW359 at Huntley, Mitchell, and Longmont and for 53AB3 at East Lansing. However, in 8 of 17 locations, the standard variety compared favorably with the local variety and this indicates its adaptability over a wide range of circumstances.

The variety-date interactions were significant at Spreckels, Sheridan, Longmont, and East Lansing. Apparently, in all four instances the local variety for the local planting and harvesting

Table 3.—Sugar Beet Climate Study, 1954, Total Beet Weight—Root Plus Crown, Grams Per Pot.

Location	Local Var.	Local Dates**	Mean Values*** A (Local Dates) SP*	B LV*	C (5/1-10/15) SP*	D LV*	LSD 5%	F Values[1] Date	Var.	DxV	Relative Values[2] A	B	C	D	Local Mean	C.V.
Berkeley, Calif.	US75	3/1-10/15	4325	3604	3331	2955	844	7.76	3.46	0.34	207	173	160	142	3554	26.2
Davis, Calif.	US75	3/1-10/15	4664	4170	2844	2991	533	64.97	0.87	2.97	224	200	136	143	3667	16.0
Spreckels, Calif.	US75	3/1-10/15	1652	2211	1647	1674	357	4.75	5.55	4.56	79	106	79	80	1796	21.9
Betteravia, Calif.	US75	2/18-9/1	1326	1761	2184	2253	285	46.32	6.48	3.40	64	84	105	108	1881	16.7
Prosser, Wash.	028	3/16-10/14	2977	3086	2579	2093	808	6.10	0.45	1.11	143	148	124	100	2684	33.2
Nampa, Idaho	US22/3	4/6-10/3	2147	2632	2487	2648	n.s.	0.69	2.27	0.57	103	126	119	127	2478	27.4
Twin Falls, Idaho	US22/3	4/15-10/16	1438	1653	1369	1565	222	0.57	6.12	0.40	69	79	66	75	1517	16.1
Logan, Utah	828	4/26-10/15	1799	1747	1904	2069	n.s.	1.46	0.10	0.38	86	84	91	99	1880	29.7
Huntley, Mont.	GW359	4/14-10/5	2660	3525	2683	4037	548	1.97	33.77	1.64	128	169	126	194	3226	18.7
Sheridan, Wyo.	MW391	5/10-10/5	1360	1765	1512	1523	205	0.41	8.46	7.59	65	85	73	73	1540	14.7
Newell, S.D.	828	4/20-10/1	1139	1132	1162	1105	n.s.	<0.01	0.04	0.03	55	54	56	53	1135	41.4
Mitchell, Neb.	GW359	4/15-10/2	1876	3690	1705	3831	741	<0.01	58.22	0.37	90	177	82	184	2776	29.4
Longmont, Colo.	GW359	4/7-10/22	1085	2662	1340	2136	430	0.72	55.19	5.98	52	128	64	102	1806	28.0
Rocky Ford, Colo.	Am. 1	4/22-10/13	990	817	940	676	247	1.22	6.44	0.28	47	39	45	32	856	31.3
E. G. Forks, Minn.	Am. 3	5/1-10/15	2282	2580	2202	2458	n.s.	0.24	1.85	0.01	109	124	106	118	2373	26.4
E. Lansing, Mich.	53AB3	4/15-10/28	3175	4903	3097	3353	696	11.25	16.69	9.19	152	235	148	161	3632	21.1
Beltsville, Md.	201-B	4/19-11/15	2560	2372	2260	1852	291	16.29	8.59	1.18	123	114	108	89	2261	14.2
National Values		5/1-10/15	2203	2607	2086	2306	.....	.....	.....	.....	106	125	100	111	.....	.....

*See footnotes to Table 2.

dates (Treatment B) did better than the standard variety (Treatment A) as one would expect. However, on the standard dates the differences favoring the local variety (Treatment D) decreased so much that only the difference at Longmont remained significant statistically.

On a national basis, the relative values for beet root yields have a much wider range than for the sugar percentages (Tables 2 and 3). In the Rocky Ford experiment the beet root growth was approximately one-third of the national average because of the curly top disease, whereas for Berkeley, Davis, and East Lansing, beet root growth was more than twice the national average. The good growth obtained at East Lansing was particularly interesting because of the low yields of field grown beets generally observed in the Michigan area. This suggests that plants receiving ample supplies of nutrients and water and kept free of plant diseases and pests produce as much in Michigan as in the best beet growing areas of the United States.

The attempts made in this study to relate storage root growth to maximum and/or minimum temperatures were without success. This is not at all surprising, since root growth is primarily a function of the surplus sugar produced each day which is essentially the sugar produced in excess of the sugar used in growth and respiratory processes. By supplying ample quantities of nutrients and water, and by maintaining the plants disease and pest free, the primary factors limiting the beet root growth are light, temperature and the genetic composition of the plant. The latter category constitutes the internal growth potential of the sugar beet plant and this limits growth when light and temperature are favorable. At other times, light and temperature are the primary factors that limit the growth of the storage root.

Sugar stored: The sucrose stored in the beet roots plus the crowns, ranged from less than 100 grams at Rocky Ford to well over 500 grams per pot at Berkeley and East Lansing (Table 4). On the average the local variety at the local planting and harvesting dates (Treatment B) produced more sugar than the standard variety at either the local or standard planting and harvesting dates (Treatments A and C). Also, the local varieties at the standard dates (Treatment D) produced nearly as much sugar on the average as the local variety at the local dates (Treatment B). These results are in accord with the data for beet root weights and sucrose concentrations (Tables 2 and 3).

The amount of sucrose stored by sugar beet plants at any one time is a function of the beet root weight and its sucrose concentration. Thus, a real gain in sucrose stored can be made

only if both sucrose concentration and yield increase simultaneously or if the yield or sucrose concentration increases faster than its complement decreases. As a rule, whenever a significant increase in sucrose stored was observed in relation to date or variety (Table 4), the increase was accompanied by a significant increase in beet root weight alone (Table 3) or in conjunction with an increase in sucrose concentration (Table 2). Whenever these effects did not carry over to sucrose stored, changes in weight or sucrose concentration cancelled each other, as for example, the variety effects at Rocky Ford and Beltsville and the date effects at Spreckels and Prosser. At Sheridan and at Mitchell, the significant effects of date on sucrose concentration and of variety on weight at Spreckels and Betteravia (Table 3) failed to carry over to the sugar stored (Table 4). Only at Huntley was the date effect on sucrose concentration (Table 2) carried over to the sugar stored (Table 4). All date and variety interactions for sugar stored (Table 4) were not significant statistically except for East Lansing, where a significant date-variety interaction for beet root weight (Table 3) carried over to the sugar stored by the beet roots (Table 4).

Crown weight as percent of crown plus root weight: Apparently the proportion of crowns to the total weight of beet root plus crown is influenced considerably by the variety and the climate in which the plants are grown (Table 5). The lowest crown percentages for the standard variety under standard conditions, Treatment C, were 8.3 and 9.6 at Prosser and Berkeley, respectively. The highest values for the standard variety, 23.3 and 27.5 were observed at East Grand Forks and Huntley, respectively. Within a climate the differences were much smaller than between climates and were associated primarily with the variety grown and occasionally with the age of the plant. In every instance, as one might expect, the crowns of the older plants formed a larger proportion of the beet root than of the younger plants. The significant effect of date on the crowns at East Grand Forks apparently is one of those events which occurs purely by chance since the local and standard dates of planting and harvesting were identical.

In the seventeen locations across the country, there were eight locations in which there was a significant variety effect on the crown percentage of the beet root (Table 5). In all instances, the highest crown percentages were associated with the standard variety, which suggests that local selections have been effective in decreasing the crowns of beet roots. In actual figures, this has meant a reduction of 2.65 percentage units or 14.7 percent for all seventeen locations.

Table 4.—Sugar Beet Climate Study, 1954, Sucrose in Root Plus Crown, Grams Per Pot.

Location	Local Var.	Local Dates**	Mean Values*** A (Local Dates) SP*	A (Local Dates) LV*	B (5/1-10/15) SP*	B (5/1-10/15) LV*	LSD 5%	F Values[1] Date	F Values[1] Var.	F Values[1] DxV	Relative Values[2] A	Relative Values[2] B	Relative Values[2] C	Relative Values[2] D	Local Mean	C.V.
Berkeley, Calif.	US75	3/1-10/15	564	504	473	409	104	6.61	2.87	0.00	214	191	179	155	487	23.6
Davis, Calif.	US75	3/1-10/15	477	453	334	337	75	24.65	0.17	0.25	181	172	127	128	400	20.9
Spreckels, Calif.	US75	3/1-10/15	172	231	206	203	n.s.	0.03	2.48	3.14	65	88	78	77	203	27.6
Betteravia, Calif.	US75	2/18-9/1	180	224	306	317	41	60.22	3.75	1.34	68	85	116	120	257	17.4
Prosser, Wash.	028	3/16-10/14	399	424	377	352	n.s.	1.50	0.01	0.43	151	161	143	133	390	29.7
Nampa, Idaho	US22/3	4/6-10/3	244	289	289	305	n.s.	0.99	0.93	0.21	92	109	109	116	282	34.6
Twin Falls, Idaho	US22/3	4/15-10/16	228	263	209	255	35	0.52	8.90	0.66	86	100	79	97	241	16.2
Logan, Utah	828	4/26-10/15	273	272	285	300	n.s.	0.59	0.07	0.10	103	103	108	114	283	29.1
Huntley, Mont.	GW359	4/14-10/5	296	420	357	500	63	10.47	37.41	0.21	112	159	135	189	393	17.6
Sheridan, Wyo.	MW391	5/10-10/5	148	191	176	184	26	1.37	8.10	3.59	56	72	67	70	175	16.5
Newell, S.D.	828	4/20-10/1	100	102	114	117	n.s.	0.78	0.03	0.00	38	39	43	44	108	48.6
Mitchell, Neb.	GW359	4/15-10/2	202	385	184	430	80	0.24	58.87	1.24	77	146	70	163	300	29.4
Longmont, Colo.	GW359	4/7-10/22	116	302	127	238	60	1.59	50.29	3.16	44	114	48	90	196	33.8
Rocky Ford, Colo.	Am. 1	4/22-10/13	115	107	103	86	n.s.	2.24	1.30	0.19	44	41	39	33	103	33.4
E. G. Forks, Minn.	Am. 3	5/1-10/15	321	355	292	338	n.s.	1.12	3.32	0.07	122	134	111	128	325	20.5
E. Lansing, Mich.	53AB3	4/15-10/28	442	654	401	423	83	22.40	16.61	10.91	167	248	152	160	480	19.0
Beltsville, Md.	201-B	4/19-11/15	246	290	236	224	47	5.41	0.97	2.88	93	110	89	85	249	20.8
National Values		5/1-10/15	266	321	264	294	----	----	----	----	101	122	100	111	----	----

*See footnotes to Table 2.

Table 5.—Sugar Beet Climate Study, 1954, Crown Weight as Percent of Root Plus Crown.

Location	Local Var.	Local Dates**	Mean Values*** A (Local Dates) SP*	A (Local Dates) LV*	B (5/1-10/15) SP*	B (5/1-10/15) LV*	LSD 5%	F Values[1] Date	Variety	DxV	Relative Values[2] A	B	C	D	Local Mean	C.V.
Berkeley, Calif.	US75	3/1-10/15	9.5	12.0	9.6	9.0	n.s.	1.73	0.74	2.07	55	70	56	53	10.0	33.7
Davis, Calif.	US75	3/1-10/15	23.7	18.3	20.0	14.5	4.4	5.98	12.55	<0.01	138	107	116	85	19.1	25.5
Spreckels, Calif.	US75	3/1-10/15	17.9	20.9	15.4	14.0	3.4	15.69	0.46	3.17	105	122	89	82	17.1	22.0
Betteravia, Calif.	US75	2/18-9/1	.....	.....	11.5	8.5	n.s.	.....	.....	.....	.....	.....	67	49	10.0	35.7
Prosser, Wash.	028	3/16-10/14	9.4	10.4	8.3	8.6	n.s.	1.34	0.28	0.07	55	60	48	50	9.2	43.0
Nampa, Idaho	US22/3	4/6-10/3	13.4	9.9	13.4	11.3	2.2	0.83	13.13	0.90	78	58	78	66	12.0	20.3
Twin Falls, Idaho	US22/3	4/15-10/16	17.2	15.8	15.0	13.7	2.4	7.08	3.20	<0.01	100	92	87	80	15.5	16.8
Logan, Utah	828	4/26-10/15	16.8	17.5	15.1	15.1	n.s.	4.35	0.13	0.13	98	102	88	88	16.1	18.7
Huntley, Mont.	GW359	4/14-10/5	28.0	22.4	27.5	25.1	4.5	0.46	6.48	1.02	163	131	160	146	25.7	19.2
Sheridan, Wyo.	MW391	5/10-10/5	21.1	18.0	22.0	18.3	2.7	0.35	12.27	0.11	123	105	128	107	19.8	15.3
Newell, S.D.	828	4/20-10/1	20.4	17.5	16.6	17.3	n.s.	1.75	0.55	1.50	119	102	97	101	18.0	25.7
Mitchell, Neb.	GW359	4/15-10/2	20.2	15.5	20.0	14.9	4.6	0.06	9.33	0.03	117	91	117	87	17.7	28.7
Longmont, Colo.	GW359	4/7-10/22	26.8	14.6	20.6	12.0	5.2	6.06	33.15	1.01	156	85	120	70	18.5	30.9
Rocky Ford, Colo.	Am. 1	4/22-10/13	14.4	10.2	13.2	8.3	3.4	1.62	15.08	0.09	84	59	77	48	11.5	32.4
E. G. Forks, Minn.	Am. 3	5/1-10/15	19.5	18.5	23.3	20.0	3.6	4.51	2.73	0.77	114	108	136	117	20.4	19.5
E. Lansing, Mich.	53AB3	4/15-10/28	19.5	22.7	19.4	15.4	4.5	5.63	0.06	5.36	114	132	113	90	19.3	25.6
Beltsville, Md.	201-B	4/19-11/15	22.0	17.2	20.8	17.6	4.5	0.06	6.52	0.25	128	100	121	102	19.4	25.7
National Values	—	5/1-10/15	18.7	16.3	17.2	14.3	.....	.....	.....	.....	109	95	100	83	.....	.....

*See footnotes to Table 2.

Table 6.—Sugar Beet Climate Study, 1954, Fresh Weight Tops, Grams/Pot

Location	Local Var.	Local Dates**	Mean Values*** A (Local Dates) SP*	B (Local Dates) LV*	C (5/1-10/15) SP*	D (5/1-10/15) LV*	LSD 5%	F Values[1] Date	Variety	DxV	Relative Values[2] A	B	C	D	Local Mean	C.V.
Berkeley, Calif.	US75	3/1-10/15	1899	1780	2373	1933	n.s.	2.34	1.86	0.61	97	91	121	99	1996	32.5
Davis, Calif.	US75	3/1-10/15	2194	1648	2026	1579	673	0.26	4.48	0.04	112	84	103	81	1862	39.8
Spreckels, Calif.	US75	3/1-10/15	1595	1691	1527	1438	n.s.	0.09	<0.01	2.02	81	86	78	73	1563	25.9
Betteravia, Calif.	US75	2/18-9/1	1309	1075	982	1070	218	4.74	0.93	4.46	67	55	50	55	1109	21.7
Prosser, Wash.	028	3/16-10/14	2773	2289	2984	2509	n.s.	0.60	2.97	<0.01	142	117	152	128	2639	33.3
Nampa, Idaho	US22/3	4/6-10/3	2236	1935	2621	2054	n.s.	1.48	4.39	0.41	114	99	134	105	2211	29.6
Twin Falls, Idaho	US22/3	4/15-10/16	1654	1730	1404	1333	196	22.31	<0.01	1.15	84	88	72	68	1530	14.1
Logan, Utah	828	4/26-10/15	1801	1673	1606	1856	n.s.	<0.01	0.19	1.82	92	85	82	95	1734	25.5
Huntley, Mont.	GW359	4/14-10/5	3801	4811	3906	4360	839	0.35	6.26	0.90	194	246	199	223	4220	21.9
Sheridan, Wyo.	MW391	5/10-10/5	2138	2178	2076	2030	n.s.	0.49	<0.01	0.08	109	111	106	104	2106	22.6
Newell, S.D.	828	4/20-10/1	2010	1726	2269	1916	n.s.	0.88	1.77	0.02	103	88	119	98	1980	38.3
Mitchell, Neb.	GW359	4/15-10/2	3336	4550	3160	3898	893	1.77	9.84	0.58	170	232	161	199	3736	26.4
Longmont, Colo.	GW359	4/7-10/22	973	1455	1177	1051	429	0.45	1.43	4.13	50	74	60	54	1164	40.6
Rocky Ford, Colo.	Am. 1	4/22-10/13	941	664	937	691	211	0.02	12.66	0.04	48	34	48	35	808	28.8
E. G. Forks, Minn.	Am. 3	5/1-10/15	1763	1626	1867	1594	n.s.	0.05	1.31	0.14	90	83	95	81	1717	32.1
E. Lansing, Mich.	53AB3	4/15-10/28	1469	2395	1730	2253	704	0.06	8.72	0.67	75	122	88	115	1962	39.6
Beltsville, Md.	201-B	4/19-11/15	706	1143	665	1275	208	0.39	51.95	1.40	36	58	34	65	947	24.2
National Values	—	5/1-10/15	1918	2024	1959	1934	—	—	—	—	98	103	100	99	—	—

*See footnotes to Table 2.

Fresh weight of tops: At the time of harvest, the largest tops, by far, were observed at Huntley, Montana, and at Mitchell, Nebraska (Table 6). Apparently, climatic conditions were favorable to top growth for both the local and standard varieties at these locations, but unfortunately, this favorable influence was not transmitted in time to beet root growth (Table 3) nor even to the sucrose concentration of the beet root (Table 2). The much smaller tops at Longmont (Table 6) for these same varieties may have been due to climate or to spider mite damage that was prevalent in that area for the first time. Similarly, curly top damage seemed to be responsible for the poor top growth of the local variety at Rocky Ford, Colorado. At all other locations, top growth appeared to be related to local climate, although minor effects of diseases and insects were quite likely associated with some of the differences observed at these locations. The poor top growth in Beltsville was not caused by disease or pests and thus seems to be related to climate.

The date effect on top growth was significant only at Twin Falls and at Betteravia (Table 6). The cause of the date effect at Twin Falls is unknown while at Betteravia the relatively low F value indicates that this effect may have been due to chance only. At all other locations, top growth appears to have been stabilized regardless of the time of planting and harvesting.

The variety effect on top growth was significant in seven out of the 17 locations (Table 6). In four of these locations, the local variety had larger tops than the standard variety. The date-variety interaction was barely significant at Betteravia, and again, this effect may have been due to chance. All other interactions were nonsignificant.

Top growth in relation to heat sums: Minimum heat sums above 32° F. accumulated for four weeks prior to harvest were also related to the fresh weight of the leaf blades and to the fresh weight of the tops. The results for the fresh weight of the tops are plotted in Figure 2. While the points deviate considerably from the freehand curve, the fresh weight of tops decreases gradually with increasing night temperatures and this agrees with the trends observed in controlled climate facilities, providing night temperatures were not too low for plant growth (6, 9).

Top growth in relation to latitude: Top growth and latitude have a correlation coefficient of +0.581, a value that is nearly significant at the 1 percent level. This relationship (Figure 3) is linear and has the equation of $y = 135.6X - 3680$, where y is the fresh weight of the tops in grams and X the degrees of

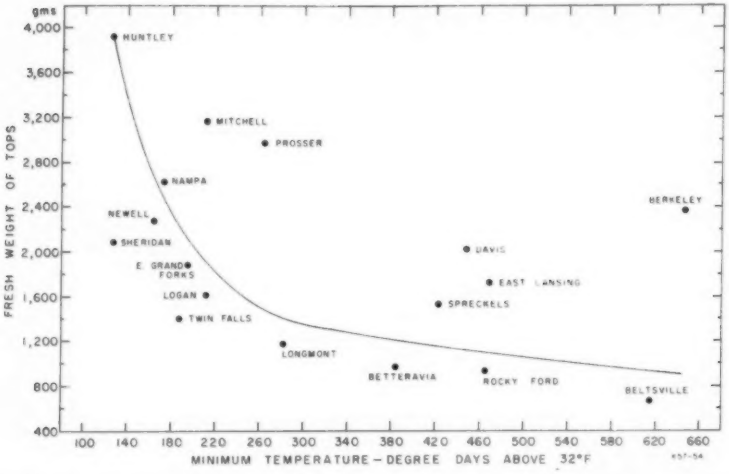

Figure 2.—Relationship of fresh weight of tops to minimum night temperatures above 32° F. summed for four weeks prior to harvest. The fresh weights of the tops are means of 10 replications of the standard variety SP53104-0 planted May 1 and harvested October 15, 1954 (Treament C).

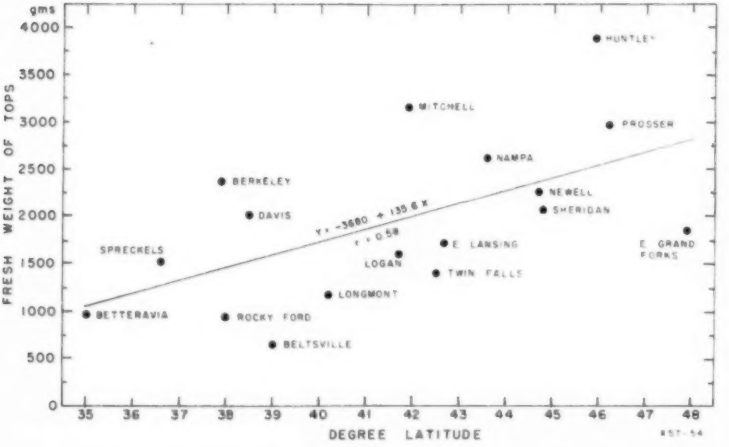

Figure 3.—Linear regression of fresh weight of tops on degrees latitude of experimental location. The top weights are means of 10 replications for the standard variety SP53104-0 planted May 1 and harvested October 15, 1954 (Treatment C).

latitude. The latitude calculated from the equation for zero top growth for the present varieties in North America is 27.1 degrees latitude. Failures of commercial plantings north of 27.1 might also take place unless the beets are planted in the fall for winter growth and spring harvests, as in the Imperial Valley in California. Also from the equation beet plantings located north of 47.9 in favorable thermal belts would apparently lead to still larger tops. This suggests that in future studies, it would be well to locate experimental trials farther north and south of the present locations if the effects of latitude on top growth are to be more clearly defined.

Discussion

It is quite realistic to conclude from the results of the present experiments that the effects of climate and of technique on the growth and sugar content of the beet plants are not readily separable from one another even though every precaution possible was taken to make climate the sole variable for the seventeen locations across the United States. However, to consider the differences between locations solely due to differences in technique is not at all reasonable nor would it be fair to attribute the differences observed between the seventeen locations as being due to climate alone. The truth lies somewhere between these two extremes even though the objective of the experiment was to observe the effect of climate alone on sugar beet plants. Only by a direct comparison of the results for two or more operators setting up an experiment in duplicate at one location can a measure of within and between operators be obtained unequivocally. Until this is done, it is still of interest to correlate plant growth, as well as the sucrose concentration for each location with pertinent climatic information such as temperature, solar energy, and day length.

One of the striking results thus far obtained has been the observation that the sucrose concentrations of the beet roots at most locations exceeded the maximum value of 12 percent as measured in the Earhart Plant Research Laboratory for comparable plants well supplied with water and plant nutrients. The reason for these high sucrose concentrations is not now known, although intuitively, the high sucrose values might be associated with a combination of warm days and cool nights not studied in the Earhart Laboratory. Also, there is the possibility that the ultraviolet light outdoors exceeded that indoors and this retarded top growth which favored sucrose accumulation.

If sugar beet climate studies are to be conducted again across the country, several changes in technique should be considered

rather carefully. One is the use of larger containers, preferably much deeper and somewhat larger in diameter. A standard item that has been found suitable during the last three years is a 10-gallon "calcium carbide container," which is 12½ inches in diameter and 20⅜ inches deep. These may be purchased new or from salvage companies. Using containers of this size, it has been found that a single watering of the plants, preferably at 10 A.M., has been sufficient to carry the plants through the hot summer days at Davis, although in the Imperial Valley, watering twice daily was necessary in midsummer when temperatures were well above 100° F. Roots in pots of this depth do not penetrate readily into the soil below the containers, and therefore, the amount of water available to the plants would be the same after each watering. In the present pots, with a capacity of 4 gallons the unequal development of roots below the pots would make for unequal availability of water, which would be a major source of variation whenever the plants are watered only once a day during hot periods. Wilting of plants can usually be avoided by watering daily between 8 A.M. and 10 A.M. or by watering when necessary twice daily.

Thought, too, should be given to the replacement of vermiculite by a material that does not collapse with time. Vermiculite by itself might be improved by a better processing technique or by a firmer packing of the vermiculite just prior to planting. The latter procedure has prevented settling of the vermiculite although its collapse still occurs when it becomes dry and re-moistened, repeatedly. Aside from this difficulty, vermiculite has the advantage of being light, holds far more water than sand, provides adequate aeration and is fairly uniform in composition (5). Losses of vermiculite from wind may be minimized by covering the surface with pea-sized gravel.

Wind damage to plants may be prevented by placing a small windbreak around the pot culture area, but this must not shade the plants during the day. Damage from hail may be circumvented by covering the plants with a hinged screen whenever a hail storm threatens the plants.

Light readings, as well as day and night temperature records, should be taken at each location if a better interpretation of the effects of local climate on sucrose concentration is to be made in future sugar beet climate studies. If light readings had been taken in 1954, these might have explained the wide range of sucrose concentrations observed for beets subjected to approximately the same heat sums prior to harvest (Figure 1). As the heat sums above 32° F. increased, sucrose concentrations decreased

as expected, except for Berkeley. In Berkeley, the clear weather prior to harvest more than likely accounted for the higher than average sucrose concentrations of these beets. A further refinement in relating heat sums to sucrose concentrations might well depend upon taking these light measurements, as well as on a more thorough study of the temperatures preceding harvest and its effects on the beet roots themselves. Thus, for example, the heat sums for four weeks prior to harvest, as plotted in Figure 1, seem to be related to sucrose concentrations better than the sums for a one-, two- or three-week period (not recorded here). Further study, however, might indicate that a time period other than four weeks would be preferable or that the base temperature of 32° F. might need to be adjusted upward or downward as more experience dictates. The taking of temperatures within the pots as well as of the atmosphere may offer further aid in the interpretation of future experimental results.

The effects of night temperature on the sucrose concentrations of the beet root (Figure 1) may not be entirely fortuitous is indicated by the orderly decrease in fresh weight of the tops as the heat sums above 32° F. increase (Figure 2). Warm days and warm nights tend to decrease the life expectancy of individual beet leaves (9) and an overall decrease in weight of the tops of the plants results (6).

A logical extension of the sugar beet climate study would be to include one or more treatments in which the plants would receive no more nitrogen at a definite time prior to harvest. Plants in treatments of this type, when compared to the full nitrogen treatment, would give a measure of sugar production under nitrogen deficient as well as under nitrogen abundant conditions. Extension of the study to locations farther north and south would add still more to our knowledge of how beets grow and accumulate sugar in different climates.

Summary

Identical experiments with sugar beet plants were conducted cooperatively at seventeen locations in the major sugar beet growing areas of the United States. The plants were grown outdoors in pots under standardized conditions, using a common substrate, nutrient solution, beet seed and common planting and harvesting times (Treatment C). These plants were compared to the local variety, planted and harvested at standard times (Treatment D), and to the local (Treatment B) and standard varieties (Treatment A), planted and harvested at local times.

The sucrose concentrations of the beet roots and the weights of the roots, crowns, and tops, as well as the minimum night and maximum day temperatures, were determined at each location. The results for each treatment were compared on a local and on a national basis and the highlights of the results are as follows:

1. The sucrose concentrations of the beet roots in many of the locations were much higher than the 12 percent observed in the controlled climate studies conducted at low night temperatures in natural light under glass. Values as high as 16.3 percent were observed in some outdoor climates. This suggests that beet plants should be studied under more combinations of controlled climates in order to discover those factors conducive to high sucrose concentrations.

2. In more than half the locations the sucrose concentrations of the beet roots formed an inverse pattern when plotted against the minimum night temperatures summed over 32° F. for four weeks prior to harvest. Differences in intensity or possibly quality of light prior to harvest are thought to be responsible for the exceptions to the inverse temperature relationship.

3. The fresh weights of the tops were found to be inversely related to the minimum night temperatures summed over 32° F. for four weeks prior to harvest. Top weight, as might be expected from the temperature records, was directly related to the latitude of the location.

4. Beet root weight was not related to minimum night temperature. Apparently beet root weight is primarily a function of the sugar not used for top growth or for respiration.

5. Crown weight is apparently a function of climate, variety and age of the plant. Warmer climates and older plants tend to be conducive to larger crowns.

6. Suggested changes in technique include larger pots, firmer substrate, wind breaks, light recorders, and the inclusion of differential nitrogen levels as one of the basic treatments in a new series of experiments. Further study of the relationship of heat sums to sucrose concentration, using different base temperatures and/or summation periods prior to harvest, is recommended. Light sums and their possible relationship to sucrose concentrations and heat sums should not be overlooked.

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Improvements in Cultural Operations Through Mechanization

AUSTIN ARMER[1]

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The urge to save time and labor in cultural operations relating to the growing of the sugar beet crop is a driving force which has induced many practical farmers as well as designers of machinery to investigate new concepts in machine operation.

In retrospect it would appear that two courses lay open to the investigators; one was the combining of cultural operations into a single complex machine which would simultaneously perform a number of tasks and the second was the facilitating of sequential operations by removing limitations of travel, speed and steering precision.

Figure 1.—1947—Jaeger & Stevens of Madison, California, equipped a tractor for listing, bed shaping, and planting in one operation.

During the late 1940's and early 50's, a considerable number of combine machines appeared in California, principally in the Woodland area. About a dozen such machines were built by individual growers and custom manufacturers (See Figures 1, 2, 3, and 4). These "planting combines" were machines mounted on sleds which in one pass over the field performed any or all of the following operations:

1. Listing
2. Bed Shaping
3. Fertilizer placement
4. Seedbed preparation
5. Planting
6. Rolling

[1] Agricultural Engineer, Spreckels Sugar Company, Woodland, California.

In practice, the saving of time and labor effected by these machines was very considerable. Furthermore, there were some very real advantages in the quality of work which was achieved. For example, the long sled runners made necessary by the multiplicity of functional components achieved a straightness of rows superior to that possible with conventional methods of seedbed preparation and planting. Further, the accuracy of row placement on the bed together with the level character of the beds made subsequent operations of mechanical thinning, cultivation and irrigation very much more satisfactory than was possible with conventional methods.

Figure 2.—1948—K. B. Fiske of Woodland, California, combined a Seaman Tiller, John Deere fertilizer applicator, listing shovels, bed roller, and Milton panters.

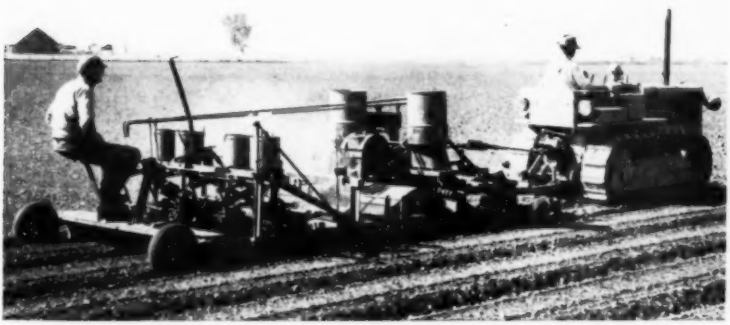

Figure 3.—1949—Tadock & Orrick of Woodland, California, built this 4-row sled which carried lister shovels, John Deere fertilizer applicators, Rototillers, rollers, and John Deere panters. Power supplied from tractor P.T.O.; hydraulic lift raised sled onto rubber tired ground wheels at rear.

There was, however, one overpowering fault. This was the need for doing as many as six operations simultaneously, whereas the demands made by soil conditions, weather conditions and other circumstances would have led to superior cultural practice if certain time intervals were to elapse between operations.

This inherent fault of the planting combine was recognized by certain individuals, probably not consciously, but was nevertheless a factor in the evolution of a sequential system of semi-

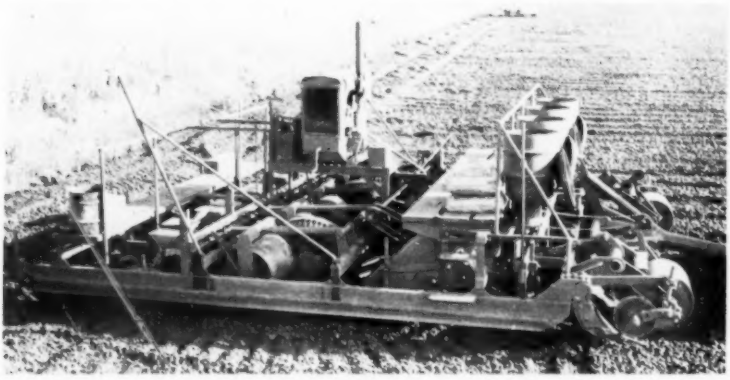

Figure 4.—1954—Heidrick Brothers of Woodland, California, built this 8-row sled which carried lister shovels, IHC fertilizer applicators, rotary tillers, rollers, and Milton planters. Power was supplied by 40 H.P. auxiliary engine; hydraulic lift raised sled for transport on rubber-tired, centrally located ground wheels which minimized turning radius.

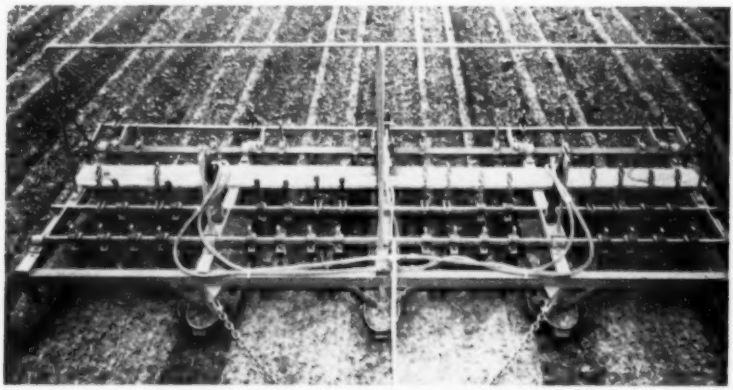

Figure 5.—1956—Arnold Collier built this "Cultivating sled" in which the furrow-following characteristics was acomplished with boat-shaped runners.

automation in cultural operations. As is so frequent with so-called "inventions" the idea occurred to several people without each other's knowledge, and at least two systems were independently developed—one by K. C. Welding, Inc. at El Centro; the other by Mr. Arnold Collier, a sugar beet grower at Dixon, California (See Figures 5 and 6).

As with the planting combine, the basic mechanization of the sequential system was a substantial sled. This sled was provided with hydraulically lifted tool bars to which could be attached the necessary tools for bed shaping, fertilizer placement, seed bed preparation, planting and rolling, and with the additional potential of accommodating tools for mechanical thinning and cultivation (See Figure 7).

By performing all of these operations in sequence with an optional time interval elapsing between operations, it became possible to perform each operation at a time best indicated by cultural environmental factors such as weather and soil conditions. The automation factor (which is not particularly self evident) lay in the fact that a sled, when drawn across a field in furrows which itself has formed, will retrace with startling accuracy its original path (See Figure 8). This accuracy of retracing is not effected by intervening irrigations or rainfall, nor by weed and crop growth on the beds or in the furrows. Further, the retracing characteristic does not require accurate tractor steering. And this in turn makes possible a substantial increase in tractor speeds.

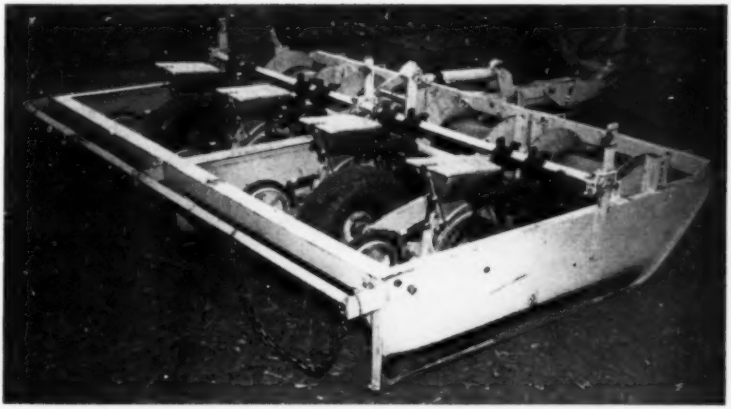

Figure 6.—1956—K. C. Welding, Inc. of El Centro, California, built this furrow-following sled with hydraulic lift raising sled onto rubber-tired ground wheels. Spool-like rollers assisted sled runners to follow corrugations; tool bar accommodated in succession Milton planters, cultivating tools, and Silver thinner cutters.

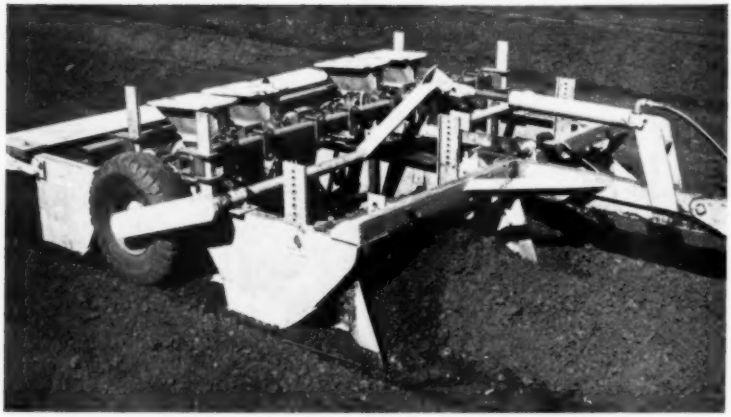

Figure 7.—1957—A later version of the K. C. sled omitted the "spools" and relied on the sled-runners alone to follow the furrow-centers.

Figure 8.—1957—The second and subsequent cultivations by the Collier sled required no accurate tractor steering; the sled runners followed the original furrows and gave accurate lateral positioning of cultivator tools.

In summary, the sequential system permits marked increases in both speed of operation and accuracy of tool placement with respect to the crop row. Here then is a new system which, rather than achieving speed at the expense of precision, achieves speed together with increased precision. The magnitude of speed increase is surprisingly large—a doubling of down-the-row speed being claimed by most users of the equipment, for all operations (planting excepted because of the limitations of planter performance as a function of speed).

Effect of Frost Defoliation on the Respiration of the Mature Sugar Beet Root[1]

D. J. Wort and D. M. Shrimpton[2]

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A study by Peto (2)[3] of the sucrose content of sugar beets used by the Canadian Sugar Factory at Raymond, Alberta, for the 20-year period 1932-1951 in relation to the first killing frost showed that a decrease in percentage sucrose was apparent within five days of the freezing. The drop in sucrose percentage in 5 days was 1.0 and in 10 days was 1.1 in 1950. It has also been shown that the drop in sucrose following top freezing may not be associated with new foliar growth (3), (4), (6). Price and Fife (5) found that sugar beets which had been topped but not lifted showed a gradual and significant decrease in percentage dry matter.

Wort and White (7) removed the tops of field grown sugar beets by frost and knife and allowed the leaves to regrow in some instances but continuously removed all regrowth in others. At intervals up to 16 days after the initial defoliation, chemical and biochemical changes in the roots were measured. The results of the various treatments did not differ significantly and frost, per se, did not initiate chemical changes or modify enzymatic sequences in a manner unlike that affected by knife defoliation. Top removal was followed by a steady increase in percentage moisture and decline in percentage sucrose, based on fresh weight. By the 16th day after defoliation, the sucrose percentage figure was 2.89 below that of control plants. On a dry weight basis, however, the sucrose percentage of roots of defoliated plants did not differ significantly from that of roots of untreated plants. It was suggested that the continual fall in sucrose percentage on a fresh weight basis was the result of continued absorption of soil water. Invert sugar was higher in treated plants and increased with time. Changes in starch-dextrin content were small. No significant alterations in total nitrogen and insoluble nitrogen were measured. The activity of catalase and phosphorylase was lower in treated plants, while phosphatase and invertase showed increased activity. Beta-amylase activity was low in all roots.

The effect of frost defoliation on the respiratory rate of the sugar beet root was studied in the experiment described below.

[1] Investigation supported by extramural research grant EMR-50 of Science Service, Canada Department of Agriculture.

[2] Professor of Plant Physiology and graduate student, Dept. of Botany, University of British Columbia, Vancouver, B. C., respectively.

[3] Numbers in parentheses refer to literature cited.

Experimental Procedure

On August 18, 1957, the leaves of 140 mature sugar beets (S.K.E.-R-11, the seed of which was supplied by the British Columbia Sugar Refining Company, Vancouver, B. C.) were frozen by covering groups of six beets with bottomless, insulated plywood boxes which contained four 20-pound blocks of dry ice (solid carbon dioxide) on wire trays. Twenty-five defoliated and 25 untreated beets were taken at random 1, 4, 8, 12, and 16 days after freezing for measurement of respiratory rates and sucrose content.

After the roots had been cleaned, trimmed, and weighed, a trans-section 3.75 cm. in height was cut from each root just below the region of greatest diameter. Trans-slices 1 mm. in thickness were cut from these cylinders by a Spencer hand microtome and from these slices, discs 1 cm. in diameter were cut by a cork borer, avoiding the periphery and the core of the beet. The discs (1 cm. diameter, 1 mm. thick) were thoroughly mixed in vessels of distilled water and after 30 minutes removed and rinsed with distilled water followed by 50 ml. of the medium described below.

Twenty discs (average fresh weight ca 1.62 g., dry weight ca 0.29 g.) were blotted dry, quickly weighed, and placed in a Warburg vessel containing a total of 4.0 ml. of solution whose composition was 0.4 M sucrose, 0.05 M phosphate buffer at pH 6.8, and 0.04 M. KCl. Carbon dioxide was absorbed by 0.2 ml. of 20 percent KOH on fluted filter paper in the center well. Nine respirometers, each containing 20 discs from the treated plants, nine containing discs of the control plants, and two employed as thermobarometers were used simultaneously at each time of respiration determination.

After 15 minutes equilibration the oxygen consumption at 25° C. was determined at 20 minute intervals for two hours. The rate of shaking was 120 strokes per minute. After respiration measurements the discs were rinsed in distilled water, blotted, and dried at 85° C. Respiration rates were computed as microliters of oxygen consumed per hour per gram fresh and per gram dry weight of the discs.

The sugar beet material not used in respiration determinations was analyzed for sucrose content by the standard method of the Association of Official Agricultural Chemists (1). The analyses were made by the British Columbia Sugar Refining Co., through the kindness of Mr. A. P. Neilson, Chief Chemist.

Results

Leaf regrowth was approximately two, four and six inches by the 8th, 12th, and 16th day after top removal.

Respiration

The respiration rates as microliters of oxygen consumed per hour on fresh and on dry weight bases are given in Table 1. Removal of the tops resulted in an immediate increase in rate of root respiration. On a fresh weight basis the maximum occurred one day after freezing and on a dry weight basis, four days after treatment. The rates steadily declined from these maxima, falling to values 20 to 30 percent below that of control roots by 16 days after treatment. The rate of respiration in the roots of untreated plants fluctuated but slightly during the term of the experiment. Respiration rates of the treated roots expressed as percent of those of the control plants are depicted in Figure 1.

Table 1.—Respiration Rates of Frost Defoliated and Control Sugar Beet Roots as Microliters of Oxygen/Hour/Gram.

		Days After Defoliation				
		1	4	8	12	16
		Fresh Weight Basis				
Defoliated:	Average*	73.6	71.7	64.6	62.0	48.4
	S.D.**	2.58	4.80	3.79	7.66	7.12
Control:	Average	67.3	68.8	70.6	68.0	67.5
	S.D.	3.14	2.22	3.99	7.50	8.49
		Dry Weight Basis				
Defoliated:	Average	392.0	400.8	352.1	333.5	281.2
	S.D.	4.99	29.26	15.61	43.22	41.57
Control:	Average	380.5	380.0	390.5	385.0	361.3
	S.D.	4.53	20.03	18.21	41.23	35.86

* Average of nine determinations

** Standard deviation

Sucrose content

The behavior with respect to sucrose percentage on a fresh weight basis was similar to that reported previously (7). The percentage in the roots of frost defoliated plants was slightly higher than that in controls one day after treatment, fell sharply by the fourth day and remained between 14.55 and 14.75 percent thereafter. In the untreated plants the sucrose percentage rose from 15.15 to 16.15 percent during the first four days of the experiment. The final values for treated and control plants were 14.60 and 16.85 percent, respectively. The values are shown in Figure 2.

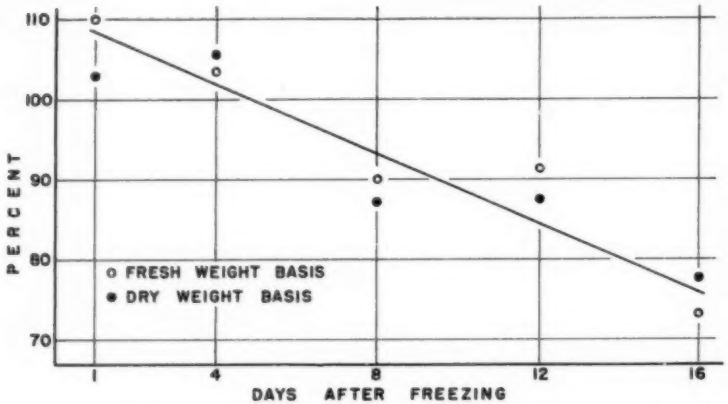

Figure 1.—Respiratory rates of frost defoliated sugar beet roots as percent of control.

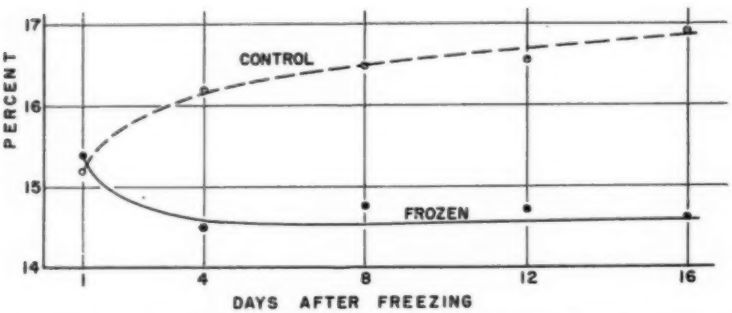

Figure 2.—Sucrose content of frost defoliated and control sugar beet roots as percent of fresh weight.

The close similarity of respiratory rates on both fresh and dry weight basis is indication that at least part of the decrease in respiration is real. A portion of the decrease in rate may be the result of a smaller protein content per unit volume of the frost defoliated beet root (7) consequent to the intake of water from the soil without its loss by transpiration. The failure to detect a respiratory rate higher than that of untreated beet roots after the initial days following defoliation, makes it unlikely that more sugar is consumed via the respiratory process in defoliated beets than in untreated plants. This coupled with the lack of significant

change in sucrose percentage on a dry weight basis and other data (7) suggests that the sucrose content of the beet root is not reduced as a result of defoliation.

Summary

Frost defoliation of mature sugar beets resulted in respiratory rates of the root tissue which were slightly higher than those of untreated plants for the first four days following defoliation but were lower than those of the controls during the balance of a 16-day period. On a fresh weight basis the percentage sucrose value dropped 0.8 in the period of the experiment. The normal increase in percentage sucrose did not occur and the final percentage value was 2.25 below that of roots of untreated plants. Evidence is cited to support the thesis that defoliation does not result in a real loss of sucrose from the beet root.

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A Study of Some Components Affecting Steffen Losses

J. R. JOHNSON AND T. C. CHURCH[1]

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Introduction and Objectives

Widely divergent Steffen losses are often encountered when lime from different geographical locations is used. The two limestones may have essentially the same composition, i.e., over 94 percent calcium carbonate with small percentages of magnesium, iron, silica, etc.

In this paper two limestones from quarries separated by approximately 350 miles are used as examples. Limestone A has for many years given exceptionally good Steffen results while limestone B has consistently resulted in high losses.

It was believed that part of the solution to the over-all problem could be found in a study of several of the factors associated with the Steffen operation. This report measures the effect of the following factors on Steffen losses.

1. Temperatures.
2. Amount of lime addition.
3. Effect of recycled materials such as Oliver filtrate and C.S.F. or Carbonation Dorr sludge.
4. Effect of vapor components used in the cold waste heater.

Limestone from quarry B contains over 96.5 percent calcium carbonate. It is very satisfactory as a defecating agent in the beet end. To date it has not proven to be as satisfactory for Steffenizing molasses as has the lime rock from quarry A which contains about 94 percent calcium carbonate. Firgue 1 points out the differences in results when the lime from the two sources are compared.

Test Method

The test data were obtained from a laboratory cooler which consisted of a Waring Blender fitted with suitable cooling coils. The cooler solution was prepared and placed in the cooler. As soon as the desired temperature was reached, a weighed quantity of lime was dumped into the cooler and the machine operated for a ten-minute period. The reacted solution was filtered and the percent sugar in cold waste determined on an aliquot. The cold waste was then seeded (if required in the test) and heated to 85° C. either on a hot plate or with vapor as outlined in the test. The hot solution was checked for settling rate, filtered, and analyzed for sugar content. This general procedure was used for all tests in order to control variables. Mill-burned and ground lime was used in all tests.

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[1] Research Chemist, The Amalgamated Sugar Co., Twin Falls, Idaho, and Nyssa Factory Technician, Nyssa, Oregon, respectively.

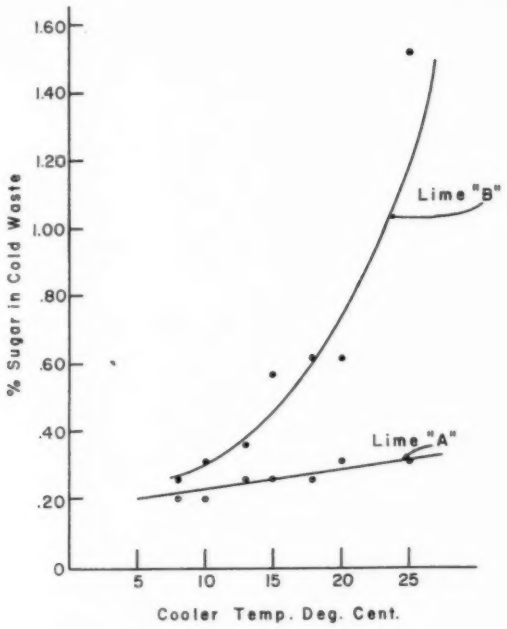

Figure 1.—Lime "A" vs. Lime "B."

Results and Conclusions

The effect of cooler temperatures at seven levels is shown in Table 1 for both A and B lime. The figures shown are means from five different ratios of lime to sugar for both cold and hot wastes at the indicated cooler temperatures.

In cold waste from lime A, differences are not significant in the range from 8 through 18° C. The 25° cooler results are significantly higher than those at all temperatures except 20° C. The trend is toward lower losses at lower cooler temperatures.

Table 1.—Effect of Cooler Temperature on Sugar in Waste.

Cooler Temp (°C.)		8	10	13	15	18	20	25	LSD (19:1)*
Cold Waste	Lime A	.25	.25	.30	.30	.31	.38	.43	.10
	Lime B	.34	.36	.44	.64	.66	.74	1.79	.16
Hot Waste	Lime A	0	0	.01	.01	.05	.06	.12	.08
	Lime B	0	0	0	.09	.14	.20	.85	.14

*Least significant difference at 19:1 odds.

Hot waste from coolers using lime A shows the same trend as does the cold waste. This indicates that very acceptable results can be expected using lime A at cooler temperatures of 20 degrees or less.

Results using lime B are more striking. In cold waste the coolers operated above 15° C. resulted in significantly higher losses than those at temperatures below 15° C. The trend toward lower losses at lower temperatures is very pronounced with high losses at 20 and 25° C.

Hot waste losses using lime B from coolers 8 through 15° C. were not significant but at 25° C. the difference is very significant.

It can be concluded that Steffen losses can be minimized by maintaining cooler temperatures as low as possible. It should also be pointed out that in every case where the temperature variable can be evaluated that the same trend exists.

Figure 2 illustrates the trend of losses for lime B at several lime addition levels at various cooler temperatures.

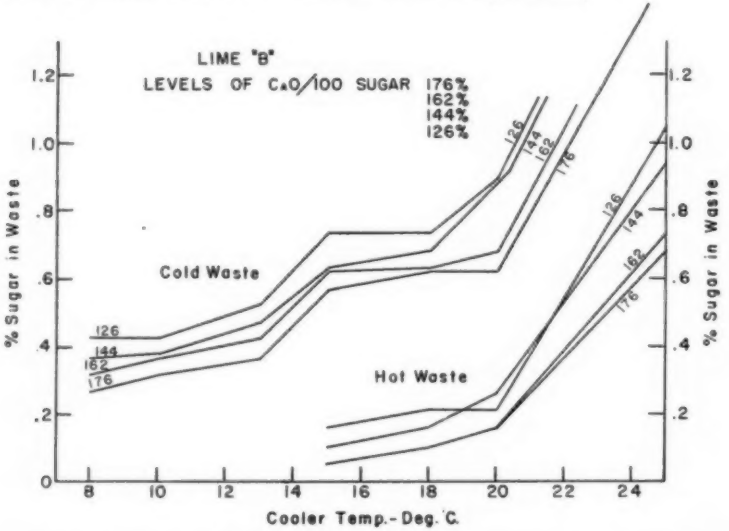

Figure 2.—Effect of lime addition and cooler temperature in controlling Steffen losses.

In Figure 3 actual factory operating data show the relationships between cooler temperature and losses taken from weekly averages at the Nyssa, Oregon, factory during the 1956 campaign. The effect that cooler temperature has on Steffen losses is masked somewhat in this figure by the apparent wide scatter of data

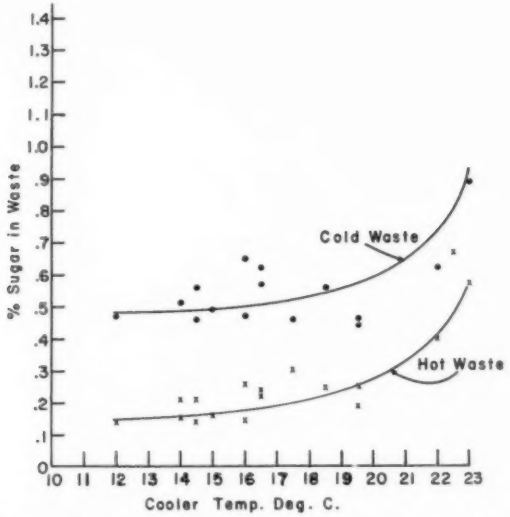

Figure 3.—Effect of cooler temperatures on losses, Nyssa Factory operating data, weekly averages.

points caused by the effect of other fluctuating variables in factory operation.

The following correlation coefficients pertaining to these data point out the significance of the main effect—temperature.

Cold Waste vs. Cooler Temperature $r = +0.63$
Hot Waste vs. Cooler Temperature $r = +0.84$
Cold Waste vs. Hot Waste $r = +0.85$
For significance (19:1 odds) $r = +0.50$

With 16 pairs, the t value calculated from the coefficients exceeds the t value for 14 degrees of fredom at a probability of .05. For significance at 19:1 odds the coefficient in each case must exceed 0.50 based on the data at hand.

It is evident that lower losses are directly associated with lower cooler temperatures under factory conditions. This association is even more pronounced in laboratory tests under controlled conditions.

Effects of Lime Addition on Steffen Losses

The data shown in Table 2 represent four levels of lime addition and are means of seven conditions of temperature for each lime.

Results using lime A show that averages in both hot and cold waste at 114 percent CaO on sugar are significantly higher than the other lime additions. The trend toward lower losses at higher lime additions is indicated.

Table 2.—Effect of Lime Addition on Losses.

Lime A					
CaO per 100 Sugar	162	146	130	114	L.S.D. (19:1)
Cold Waste % Sugar	.26	.26	.32	.42	.06
Hot Waste % Sugar	.01	.01	.03	.09	.05
Lime B					
CaO per 100 Sugar	176	162	144	126	L.S.D. (19:1)
Cold Waste % Sugar	.61	.65	.76	.83	.16
Hot Waste % Sugar	.14	.15	.21	.23	.09

Results with lime B show that 126 percent CaO on sugar causes significantly higher losses than the other treatments in cold waste except 144. The hot waste value at 126 percent CaO is significantly higher than results at 176 percent CaO per 100 sugar. Considering the trend, both hot and cold waste losses are minimized at higher lime additions. This factor, however, is not strong enough to overcome the increased losses due to high cooler temperatures.

Effect of Recirculated Material on Steffen Losses

The practice of using Oliver filtrate and carbonation Dorr sludge to replace a portion of the water normally used in preparing solutions for the cooler has been used at all of the Amalgamated Sugar Company's Steffen factories the past three years. Results indicate that recirculating a portion of these materials is not detrimental to the Steffen operation. The benefit of recycling is measured in higher brix feed to C.S.F. plant evaporators, and a reduction in the quantity of sugar lost in the Steffen process.

The evaluation of this practice and its effect on Steffen losses is summarized in Table 3 showing averages at all temperatures using lime B.

The L.S.D. values in Table 3 are shown to point up the fact that while differences in sugar losses were not significant up to approximately a 50 percent recycle load, differences may become significant at higher recycle levels. Solution 2 at 144 percent CaO is significantly higher than results with solution 1 in cold waste. This difference however is not demonstrated in the corresponding hot waste sugar loss.

Therefore, it is concluded that with up to 50 percent of the cooler solution make-up water replaced with sludge and filtrate, that the percent sugar in losses does not differ significantly. The

full benefit of using a portion of these materials to replace cooler solution water is borne out by the fact that not only is the percent sugar in the final wastes not significantly affected, but there is also a considerable reduction in the total volume of waste leaving the plant. This reduction in volume represents a lower total sugar loss.

Figure 4 graphically shows the effects of recycling sludge and filtrate and the effects of cooler temperature.

Table 3.—Effect of Recycle Material on Losses.

Solution 1—Coolers made up with water
Solution 2—62% water, 28% filtrate
Solution 3—56% water, 28% filtrate, 16% C.S.F. sludge

Two lime levels, 176% and 144%, were used with the above solutions a seven different cooler temperaturs.

Solution	1	2	3	LSD (19:1)
176% CaO on Sugar				
Sugar in Cold Waste	.61	.67	.69	.09
Sugar in Hot Waste	.14	.17	.17	.07
144% CaO on Sugar				
Sugar in Cold Waste	.76	.91	.83	.11
Sugar in Hot Waste	.21	.28	.21	.10

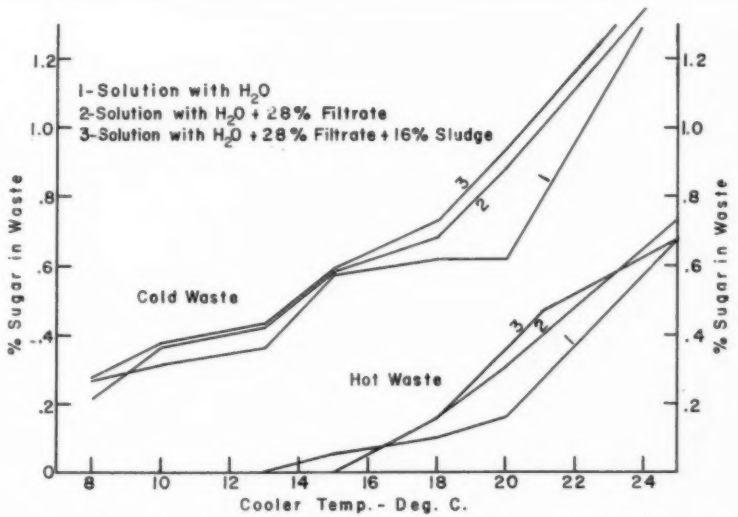

Figure 4.—Effect of filtrate and filtrate plus sludge on Steffen losses using lime at 176 percent CaO on Sugar.

Effect of Vapor Components on Cold Waste Heater Operation

Analysis has shown the presence of various ions and ammonia in condensed water from exhaust steam, 1st and 2nd vapors. Table 4 shows the relative concentration of a few of the ionic constituents found in condensed vapors.

Table 4.—Phenolphthalein-Methyl Orange Titrations of Factory Vapors.

		End Points/500 ml.		p.p.m. ions Present in Factory Vapors		
Vapor	Run	P	M O	$CO_3^=$	HCO_3^-	OH^-
Exhaust	1	0.8	2.1	171	109	
Exhaust	2	0.9	1.3	86		30
1st Vapor	1	2.4	4.9	513	22	
1st Vapor	2	1.8	3.2	300		24
2nd Vapor	1	7.5	22.5	1605	1632	
2nd Vapor	2	7.1	11.7	984		152

Cold waste was treated with various amounts of ammonium carbonate, heated to 88° C., filtered and the percent sugar determined in the filtrate. The averages of these tests are as follows:

	p.p.m. Ammonium Carbonate Added					
	0	172	344	516	688	LSD (19:1)
Hot Waste Sugar Avg. 6 Tests	.21	.24	.24	.28	.30	.04

Results show that up to 344 p.p.m. ammonium carbonate differences are not significant. The trend is toward higher losses as the carbonate ion increases. The amount of ammonium carbonate present in waste from condensed 2nd vapor is usually less than 260 p.p.m. If part of the heating is done with exhaust or 1st vapor, the concentration of these constituents could be less.

Cold waste from a series of laboratory coolers was next heated by using the electric hot plate, directly with exhaust steam, and both first and second vapors. The sugar content of the resulting hot wastes is as follows:

Heating Medium	Hot Plate	Exhaust	1st Vapor	2nd Vapor	LSD (19:1)
% Sugar (Avg. 3 Tests)	.03	.03	.08	.08	.06

It is concluded that the effect of vapor components on sugar loss is not significant under normal conditions. The trend is toward higher sugar losses as the carbonate ion is increased.

Summary

The effect of the fineness of lime has been omitted from this report. The analysis of the effects of this factor pointed to the possibility that a significant difference in the fineness of lime used for the tests did not exist. The real effect of this factor is well known to the industry.

In summarizing the main effects of the factors studied the necessity of maintaining cooler temperatures below 18° C. is the most important if low sugar losses are to be realized. Satisfactory losses can be obtained with lime from either of the two sources providing the proper temperatures are used in the Steffen house.

The effect of recycling filtrate and sludge is twofold. The increased brix of feed to a C.S.F. plant represents a saving in fuel and the reduction of sugar loss at this point increases the amount of sugar for extraction.

The amount of lime used for Steffenizing should be held to a minimum consistent with desired results. Additional lime over and above 140 percent CaO on sugar will not depress sugar losses as strongly as will proper control of the cooler temperature.

The general effects of each of the factors are well known to the industry, however there appear to be certain control levels inherent to each type of limerock for the best over-all operation.

Studies in the Measurement and Evaluation of Crystallization Velocity

HUGH G. ROUNDS AND PAUL C. KUNKEL[1]

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The need for knowledge of the crystallizing qualities of the sugar-end liquors has long been recognized, for crystallization rates are important controlling factors in the economics of sugar production. Information relative to the crystallizing characteristics of liquors in process would greatly assist operators in maintaining maximum extraction. This project was initiated for the purpose of developing and testing a laboratory method at the factory level for estimating crystallization rates and to study the effect of nonsugars on crystallization rates.

Fundamentally the rate of growth of crystals in the mother liquor can be determined either by measurement of changes in crystal size or weight, or indirectly by the measurement of changes occuring in the mother liquor and calculating such changes as crystallization. Both methods are in common use. A method for control purposes, however, imposes the following limitations:

1. The method must be rapid enough to allow the use of the result while the liquor is still available.
2. The method must be simple enough to be performed by the ordinary laboratory technician.
3. The method should require a minimum of additional laboratory space and equipment.

Of the various procedures which were considered, those which involve the measurement of changes in the mother liquor seemed to offer the greatest possibility of succeeding at the factory level.

The refractometer offers a suitable means of observing changes in concentration of a supersaturated sample of liquor undergoing crystallization. The observed changes in concentration when made with respect to time can be used as a comparative indication of the crystallization rate of the liquor. This principle has been used by several investigators, among them Van Hook (1)[2], Harris et. al. (2), and Rorabaugh and Norman (3).

Van Hook has proposed a procedure (1) for determining crystallization velocity and mellassigenic characteristics of liquors through the use of the refractometer. The method is reported to give values which compare favorably with the accepted data of Kucharenko. The method adopted for our own studies in crystallization is the Van Hook procedure modified and simplified into a possible control method. This modification, while it does not result in an estimate of the absolute crystallization

[1] Supervisor, Central Laboratory and Research Chemist respectively, The Amalgamated Sugar Company, Twin Falls, Idaho.

velocity as is possible from the Van Hook Procedure, does provide suitable values to be used for comparative purposes.

The method is generally described as follows:

1. From single or double acid true purity determinations of liquors that are to be compared, calculated amounts of pure sucrose and water are added to the liquors to adjust purity and solids concentration to standardized values. Final adjustment of solids content can be made by water addition or by evaporation. The concentration should place the sample at a supersaturated level of between 1.1 and 1.2 when calculated as follows:

$$S = \frac{\text{Ratio of Sucrose to Water}}{\text{Ratio of Sucrose to Water in saturated solution at the same temperature and purity}}$$

Where S is the degree of supersaturation

2. Each sample is cooled to 20° C, and two to four 30 gram aliquots from each sample are weighed into test tubes. Each aliquot is seeded with stock fondant sugar, amounts ranging from 0.25% to 0.30% of total sucrose present with exactly the same quantity being used for each aliquot of each sample being compared.

3. The seed is thoroughly mixed into the syrup, which establishes zero time. The aliquots are kept sealed at 20° C. until the final time is reached, which may be taken from 30 to 120 minutes, depending on purity, supersaturation, and the amount of seed used. Experience will show the minimum time required to demonstrate significant differences between samples for the conditions chosen. No crystals have been observed to settle out for crystallization periods up to two hours; therefore, it is not necessary to agitate the slurry after the initial mixing of seed and syrup.

At the end of the designated time a thick smear of the seeded syrup is placed between the prisms of the refractometer and the reading made directly.

4. The calculations are made from the following formula:

$$\text{Crystallization Rate} = \frac{C_o - C}{T} \times 1000$$

Where: C_o = Original concentration, grams total solids per 100 grams water.

C = Final concentration, grams total solids per 100 grams of water.

T = Total time in minutes.

[2] Numbers in parentheses refer to literature cited.

The results will be the average milligrams of sugar crystallized per 100 grams water per minute.
The results from the aliquots are averaged to give the sample value.

For true comparisons between samples, the factors of starting purity, starting total solids concentration, amount of seed, time, and temperature must be maintained accurately constant.

The Bausch and Lomb Precision Refractometer is satisfactory for the purpose of this method. However, some experience is required to make an accurate concentration determination by direct reading method. The test temperature of 20° C. was chosen to correspond to the normal refractometer operating temperature coincident with thermostating the seeded aliquots in the refractometer water bath.

The total time requirement for this procedure will vary with the characteristics of the original liquor which requires purity and concentration adjustment, and the length of the crystallization period. Starting with molasses of known purity and concentration and using granular sugar to adjust purity, about two hours are required to prepare the material for crystallization. To obtain significant concentration changes in one hour or less, the purity of the samples should not be less than about 85 percent true purity. It is believed that at the factory level the total time for the determination can be reduced to about two hours.

Application of Method

This procedure was used by Central Laboratory to compare crystallization rates of liquors from The Amalgamated Sugar Company's factories during the 1956-57 campaign. In this case, weekly molasses composites were adjusted to 85 purity, and 74.1 RDS. The seeding ratio was 0.3 percent seed on sucrose present and crystallization was allowed to proceed for 60 minutes at 20° C.

The results for all factories operating over 100 days (on storage beets after about the first 30 days) showed a steady decline in crystallization rate as the processing period progressed. Also, observed results for straight house operations consistently showed higher velocities than their adjacent Steffens house operations. Figure 1 is typical of these data.

The level of certain impurities in the liquor was followed along with the crystallizing quality tests, and it was of particular interest to note that the decline in crystallization rate was accompanied by a general rise in raffinose content. This is also demonstrated in Figure 1.

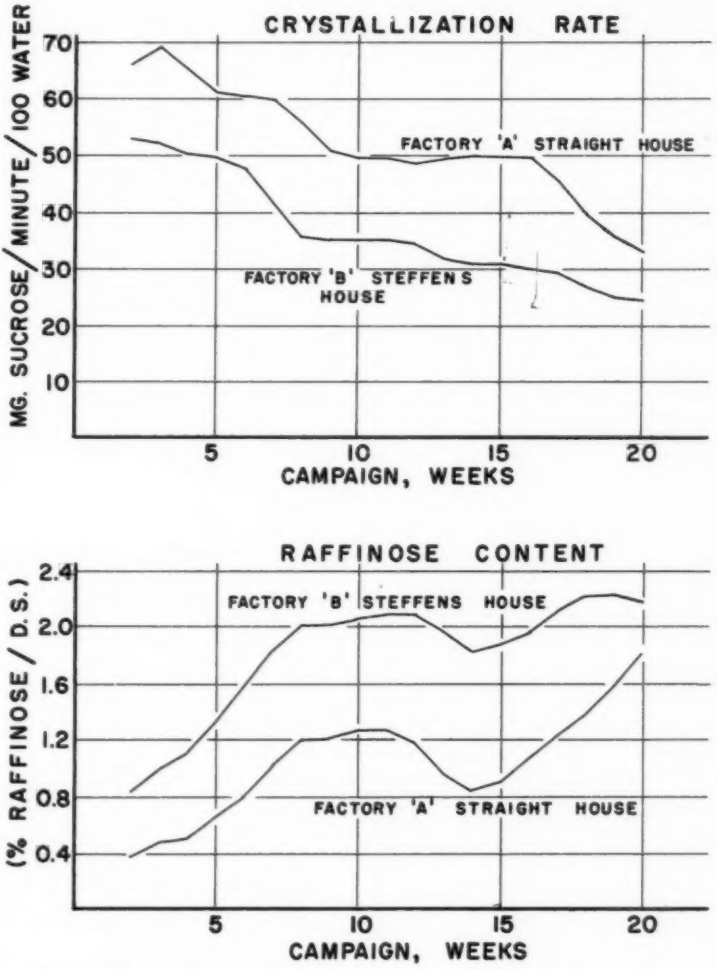

Figure 1.—Crystallization rate and raffinose content of adjacent Steffens house and straight house factories.

This lead to further studies involving raffinose in which a sample of liquor from one factory, having a low raffinose content, was adjusted to the raffinose level of a sample from another factory which was higher, and the crystallization rates then compared. Table 1 shows the results of several of such tests.

Table 1.—Comparison of Crystallization Rates of Liquors from Different Factories and the Same Liquors with Equalized Raffinose Content.

Test	Factory A (Original)	Factory B (Original)	Factory A (Adjusted)
1. Raffinose, % on RDS	0.85	2.15	2.15
Crystallization Rate*	65	33	26
2. Raffinose, % on RDS	1.03	2.25	2.25
Crystallization Rate*	58	23	21
3. Raffinose, % on RDS	1.24	2.21	2.25
Crystallization Rate*	63	23	29

*mg. sucrose/100 water/minute

This procedure was also used to compare the individual effect of various impurities on the crystallization rate of sucrose solutions. The impurities were added in the amount of 0.5 grams per 100 grams of sucrose to make a supersaturated solution of 70.6 percent solids. Crystallization rates of these solutions were compared with the crystallization rate of a pure sucrose solution at the same total solids concentration. These results are shown graphically in Figure 2. The order of magnitude of the melassigenic effects exhibited here compares favorably with the work of others (3) except in the case of betaine.

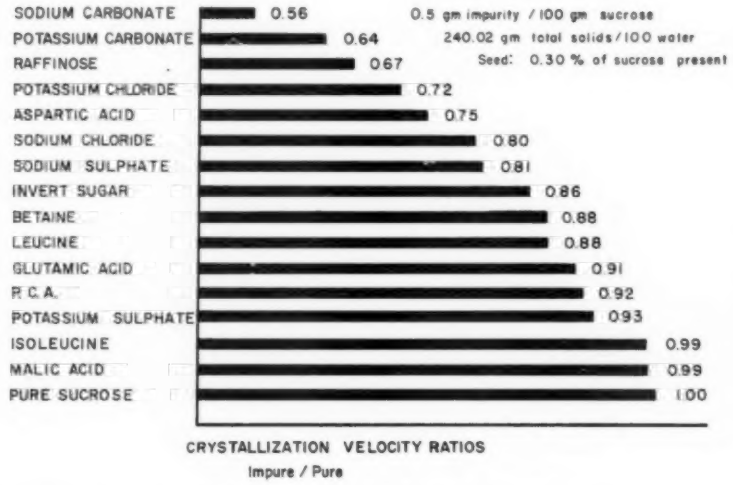

Figure 2.—Velocity ratios of crystallization for pure and impure sucrose solutions.

Summary

A method for determining crystallization rates of beet sugar house syrups and the effect of specific impurities on crystallization rate is presented.

The essential procedure involves a determination of true purity of the syrup, adjustment of purity and solids concentration to standardized values; and finally, determination of comparative crystallization rates of the standardized syrups by use of a refractometer. The time required for the procedure is approximately two hours under ideal conditions.

Crystallization rates of weekly molasses samples for the 1956-57 campaign indicates a decreasing crystallization potential as campaign progresses and correlates highly with increasing raffinose content.

The effect of specific impurities on crystallization rate has been determined and agrees, with minor exceptions, with other investigations.

Experiences in the use of this refractometer procedure indicate that it has good possibilities of succeeding as a factory control method. Further refinements are under consideration which, it is hoped, will make the method even more acceptable for this purpose.

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Planting Equipment for Monogerm Seed[1]

R. D. BARMINGTON[2]

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The possibility of having true monogerm sugar beet seed in the near future makes it very important for us to see where we stand on the problem of machinery for planting this seed. Designing a machine to accurately plant a seed before the seed is fully developed is a problem that plagues the implement manufacturer. The sugar beet industry has come to the point now where plant breeders can tell it what to expect from the new seed with respect to size, shape, and density. Any real changes in this pattern will take more years of diligent work by the plant breeders and, in the meantime, it will be necessary for farmers to plant the seed in its present state of development or developments made in the very near future.

The writer's sympathies are with the implement manufacturers and plant breeders in seeking a satisfactory solution to the problem, however, it is not felt that the situation is hopeless. Of chief concern is that both plant breeders and implement manufacturers may relax their efforts before a completely satisfactory solution is reached. In the beginning of the development of monogerm seed one plant breeder made the statement that monogerm seed could be made any size and shape wanted. While this is believed to be true, if taken over a long enough period of time, it is going to be necessary to work out some satisfactory compromises before the ultimate is reached.

To clarify some points it may be well to re-examine some of the requirements of planting equipment, whether it be for sugar beets or some other crop. First, the seed must be handled in such a way that it is not damaged to the extent that germination is affected. Second, the seed must be metered and conveyed to the bottom of the furrow in a uniformly distributed pattern. Third, the seed must be placed in the soil in such a way that all the factors affecting germination will be as favorable as possible. In this age of chemical agriculture more demands are made upon the beet planter from the standpoint of fitting into the over-all system. It is becoming increasingly important to plan for the application of chemical weed killers, fungicides, and fertilizers at the time of planting. These materials may be either in the dry or liquid form and may be applied either to the sur-

[1] Scientific Journal Series No. 544, Colorado Agricultural Experiment Station.
[2] Associate Research Engineer, Agricultural Engineering Section, Colorado Agricultural Experiment Station, Colorado State University, Fort Collins, Colorado.
[3] Numbers in parentheses refer to literature cited.

face or below the surface of the soil. As the requirements placed upon the planting equipment increase so do the problems of the design engineer increase and the final machine becomes a series of compromises so that each part and requirement will fit in with all other parts and requirements.

Some of the requirements need to be examined more carefully. Real concern for the effect of mechanical seed damage upon germination of sugar beet seed has been expressed by plant breeders[3]. Limited laboratory germination tests conducted by the writer have shown that by running sugar beet seed through one sugar beet planter the germination was reduced 8 percent as determined by a blotter test and no measure was made of the seeds which germinated but did not develop normally. In 1944 Tolman and Stout (1) [4] reported before this Society that 12 to 15 percent of the segmented seed tested developed abnormally due to mechanical injury in the segmenting process. Field observations of planter tests made during the last four years have shown plants following some machines to be more vigorous in early stages of growth. There are several design differences between the several machines, but it is also true that the healthier appearing plants followed machines which handle the seed with a very minimum of damage in the metering device. It may well be that abnormal germination due to mechanical seed damage is a factor in early plant development.

Probably the most important single requirement of a planter with respect to monogerm seed is the ability of the machine to accurately space the seed in the soil without multiple seed units or skips between the units occuring in the row. Nothing is gained from the use of monogerm seed from the standpoint of mechanical thinning if uniform distribution is not a reality. A search of domestic and foreign planters has failed to reveal any truly satisfactory machine for distributing monogerm sugar beet seed. However, some of the foreign built machines handle the seed with much less cracking and damage to the seed.

A rather extensive field testing program is being planned jointly by the Colorado Agricultural Experiment Station and The Great Western Sugar Company for domestic and foreign built planters and experimental machines using a monogerm seed exclusively. The tests will be made in farmers' fields in all types of soil in an effort to get an indication of what may be expected from monogerm seed compared with processed seed and the type of planters best suited for planting at this time.

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[3] Communication with Dr. H. E. Brewbaker, plant breeder, The Great Western Sugar Company.

Distribution usually begins with some kind of seed cells in either metal plates or rubber belts, and it would seem that at this point seed spacing should be accurate except for empty cells or multiple seeds in a single cell. After the seed leaves the seed cells, everything seems to go wrong from a distribution standpoint. Based on a system of evaluation (2) which gives a planter a score of 100 if all the seeds are placed in the bottom of the furrow in the theoretically calculated place, a score of zero if only half of the seeds are properly spaced and negative values if less than half are properly spaced, it appears that planters which discharge the seed from the hopper near the bottom of the furcell fill and distribution on a limited number of planters comparing polished monogerm seed with segmented multigerm seed. Small smooth tubes from the seed hopper to a point near the bottom of the furrow seem to be about the only improvement that has been made in several years to planters carrying the seed hopper 14 inches or more above the furrow. International and John Deere use the smooth tube design while low hopper discharge is used by Milton, Ventura, Taxigraine, and Stanhay.

In an attempt to improve seed distribution in a conventional plate type planter, a John Deere No. 70 unit was revised so the seed knocker was replaced by an air ejection device and a ¼-inch copper seed tube was used to give the system an "air rifle" effect. Air pressure from 5 to 30 pounds per square inch were used but distribution, as shown in Table 1, was poorer than when the standard star wheel knocker and seed tube were used.

The seed used in the laboratory test was screened to sizes 8 to 10/64 for both segmented and monogerm. The monogerm seed was polished in a special machine, but the polishing process did not remove much of the outside corky material. Both lots of seed were obtained from The Great Western Sugar Company where it had been processed. The segmented seed was screened in the Colorado State University laboratory to the 8 to 10/64 inch size from seed which was originally sized 7 to 10/64 inch. The monogerm seed was screened to the 8 to 10/64 inch size before it was delivered to the University. Other monogerm seed has been obtained for experimental planter work from the American Crystal Sugar Company, but it all has a very strong tendency toward flatness and present equipment for polishing seems to preserve the flat characteristic.

Even though the two types of seed were screend to the same size range, there is a great deal of difference in physical characteristics. This lot of segmented seed contains 39,900 seed pieces per pound while the monogerm seed has 49,400 pieces per pound. The flatness of monogerm seed is the thing that is most notice-

Table 1.—Laboratory Planter Performance Test.

Planter	Seed	Average Percent Cell Fill	Average Percent Seed Damage	Average Distribution Score[3]
John Deere No. 70 Plate Cells 11/64"	Segmented[1]	84.5	1.53	—11.
	Monogerm[2]	113.3	4.59	—3.3
John Deere No. 70 Plate Cells 11/64" Air Ejection	Segmented	78.7	2.98	—17.6
	Monogerm	100.2	5.17	—24.3
Milton Plate Cells 11-9½-9½	Segmented	85.8	3.83	+10.
	Monogerm	113.5	5.27	—1.3
Stanhay Belt Cells 11/64" +	Segmented	91.5	Nil	+22.3
	Monogerm	117.2	0.5	+19.3

[1] Commercial segmented seed screened 8-10/64". 39,900 seeds per pound.

[2] Polished monogerm seed screend 8-10/64". 49,400 seeds per pound.

[3] With this system a planter may have a score of + 100 for perfect distribution or —100 if none of the seeds were deposited in the proper position. Half the seeds properly spaced gives a score of zero.

able. The average thickness of the 8 to 10/64 inch monogerm seed as determined by a large number of measurements made with a micrometer was .082 inches. Measurements made on the same lot of polished monogerm seed in the 10 to 12/64 inch size range showed the thickness to be .087 inches, a difference of only .005 of an inch. The major diameter of the seed in these two size ranges increased an average of .031 of an inch for the larger seed. It appears from this that even the larger diameter monogerm seeds are only slightly thicker than the smaller seeds.

The corky material around the edge of the flat monogerm seed is relatively easy to break off to make the seed more nearly spherical, but present decorticating machines and polishing equipment seem to make the flat seed even flatter rather than orienting it so the softer material is broken off. Development of new-processing machines to do this would be a material aid in more accurate metering of the seed. It is known that pelleted seed, which is round and dense, can be planted with a high degree of accuracy. If dependable field emergence could be obtained from using pelleted seed, this would probably be a satisfactory answer. Since the use of pelleted seed has not proven universally satisfactory in the field, the next best thing seems to be to make the seed as near spherical as possible and as large and dense as it can be made through developments in plant breeding.

The problems of getting field emergence are essentially the same for monogerm seed as they are for any other sugar beet seed. Some increase in the size of the seed kernel itself has been accomplished by plant breeders so more plant food is available to the young seedling in th early stages of growth. Accurate control of planting depth and proper presswheel action is essential for good emergence. Proper presswheel and soil manipulation seem to be different in different beet growing areas. In the Rocky Mountain region it is practically impossible to pack the soil around the seed too much. Reports from Michigan indicate that a minimum of seedbed preparation (3) and packing with presswheels is superior to the many operations and firm seedbeds desirable in the mountain states. Even though these differences need attention, they are no different for monogerm seed than they are for other beet seed in common use.

In general it can be concluded that the problems of planting monogerm seed are much the same as for any other type of sugar beet seed now in general use, but the flat nature of the seed makes it more difficult to handle. Present planting equipment and the present stage of seed development has not reached a point where we can realize the ultimate benefits from the use of this seed. Monogerm seed is new to us from the standpoint of planting for commercial use and like all new things presents many problems. There seems to be great hope for a bright future in mechanization through the use of monogerm seed and other new developments which are still in the dream stage.

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Effect of Gibberellic Acid on Germination, Sucrose, and Yield of Sugar Beets

DONALD F. PETERSON[1]

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Gibberellic acid has been tested on sugar beets primarily as a tool to shorten the reproductive cycle by reducing the necessary photo-thermal induction period. In other crops, reports of increased yields have been made yet there is no information available on the effect of gibberellic acid on the yield and sucrose content of the sugar beet crop.

This paper reports the effect of spraying gibberellic acid on sugar beet seed and subsequent effects on germination as well as spraying gibberellic acid on the growing plants and the effect of this treatment on the yield and sucrose content of the sugar beet crop.

Materials and Methods

The source of gibberellic acid used in this test was the potassium salt of gibberellic acid. Immediately prior to planting, three groups of seed of variety MW 161 were sprayed with 9 cc. of gibberellic acid solution, one group 1000 p.p.m., a second 100 p.p.m., and a third 10 p.p.m. This seed, as well as the untreated seed for the check plot, was planted at a one-inch spacing in order that differences in germination might be checked. All plots in which spray applications to plants were to be made were planted at the regular fifteen pound per acre planting rate. Due to limited amounts of gibberellic acid available, plot size was limited to two rows by fifteen feet, with five replications of each treatment. Only one row of each plot was treated and harvested. The second served as a guard row to prevent drift to adjacent plots. Spray treatments were applied with a Hudson hand sprayer. Ten cc. of the proper spray solution was measured into the sprayer and applied to each plant individually. Spray applications were made at concentrations of 10, 100, and 500 p.p.m. Rate of application was about 60 gallons per acre. Dates of application were July 1, August 1, and September 1. Also, two combination treatments of (1) August 1, September 1, and (2) July 1, August 1, September 1 were made. The plots were harvested in the usual manner and all beets in each plot were harvested for yield and sucrose analysis.

[1] Plant Breeder, Holly Sugar Corporation, Sheridan, Wyoming.

Experimental Results

Seed Spray Results

Stand counts and vigor ratings made at time of emergence showed no differences between the check and the three seed spray treatments of 10, 100 and 1000 p.p.m. gibberellic acid.

Plant Spray Results

The yield data for the plant spray treatments described above are presented in Table 1.

Table 1.—Yield Data for Plant Spray Treatments Using Gibberellic Acid at Sheridan, Wyoming, in 1957.

Application[1]		Yield		Percent Sucrose[2]
Date	Conc. p.p.m.	S/A	T/A	
Check		5013	16.512	15.13
7/1	10	4903	15.959	15.36
	100	4908	16.157	15.15
8/1	10	4880	16.117	15.14
	100	4950	16.315	15.17
9/1	10	4658	15.444	15.08
	100	4982	17.820	13.98
	500	4920	18.414	13.36
8/1, 9/1	10	4968	16.751	14.83
	100	4645	16.196	14.34
7/1, 8/1, 9/1	10	4514	15.088	14.96
	100	4781	16.751	14.27
LSD (5%)		NS	NS	.76

[1] Rate of application was about 60 gal. per acre.
[2] Underlined values differ significantly from the check.

Because of the small plot size and few replications, experimental error was high. Significant differences were obtained for percent sucrose only.

Applications of gibberellic acid applied July 1 and August 1 had no significant effect on sucrose or yield of sugar beets at harvest time. Applications of gibberellic acid applied September 1 reduced percent sucrose significantly in concentrations of 100 and 500 p.p.m. Although the tonnage figures do not differ significantly, there are indications that the reduction in percent suc-

rose was accompanied by an increase in tonnage as shown by the figure of 18.414 tons per acre for the 500 p.p.m. application made on September 1.

Sugar per acre for all treatments did not differ significantly from the check.

Summary

1. Spray applications of gibberellic acid were made on sugar beet seed and sugar beet plants. Applications were made to seed in three concentrations prior to planting. Applications were made to plants in three concentrations at three dates and two combinations of dates.

2. Spray application of gibberellic acid did not affect percent or vigor of germination of sugar beet seed.

3. Spray application of gibberellic acid in concentrations of 100 and 500 p.p.m. on growing plants reduced sucrose and tended to show an increase in tons per acre without changing yield of sugar per acre.

Effects of Some Soil Treatments on Yield of Sugar Beets in Soil Infected with Sugar Beet Nematode and Rhizoctonia Root Rot

E. M. Holst and C. E. Cormany[1]

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Introduction

It has been frequently observed that the presence of nematode and root rots of several kinds can materially reduce stands and vigor of sugar beets.

Such a condition has appeared in a small field devoted to leaf spot indexing at the Holly Experiment Station near Swink, Colorado.

Since the area involved is small so that rotation cannot be relied upon for control, direct treatments of the soil have been made. Several of the treatments are too expensive for practical use.

This paper reports the first year's results on a series of soil treatments at the above location.

Procedure

The treatments used are described in Table 1.

The chloropicrin was applied by hand injection six inches deep. After marking the plots at one-foot intervals, longitudinally and laterally, the gun was calibrated to deliver three cubic centimeters per injection and this amount injected into each square foot.

Using a barrel, power take-off pump, and jet nozzles, a spray rig was built to apply other materials. The jet nozzles led into rubber tubing which led to a one-quarter inch pipe welded to a diamond point and set to discharge just behind the diamond point. The jet nozzles were used as the controlling orifice for discharge. After leaving the nozzles, the material flow was due to gravity.

Nozzle pressure, tractor speed, and dilution of material were adjustable to allow calibration. After calibration of nozzles with water, tractor speed and pump pressure were set at three feet per second and fifty pounds per square inch, respectively.

Flow of each material varied. After determining rate of flow with the various materials, dilutions were made to approximate the rates required. Actual measurements were then made to determine the amounts delivered.

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[1] Associate Agronomist, Swink, Colorado, and Chief Agronomist, Sheridan, Wyoming, respectively, Holly Sugar Corporation.

Table 1.—Materials and Rates Used in Soil Treatments.

Treatment	Material	Chemical		Rate of Application
1.	Tear Gas	Chloropicrin		33.5 gal. per acre
2.	Telone	Undiluted technical dichloropropenes		25 gal. per acre
3.	MC-2	Methyl bromide Chloropicrin	98% 2%	800 lbs. per acre
4.	Mylone	(3.5 dimethyltetrahydro 1,3-5,2H thiadiazine-2-thione)	85%	300 lbs. per acre
5.	Vapam	Sodium n-methyldithio-carbamate, anhydrous		430 lbs. per acre
6.	DD	Dichloropropene-dichloropropane		20 gal. per acre
7.	Nemagon	1.2 dibromo-3 chloropropane		25 gal. per acre
8.	Molasses-Pulp Pellets	Protein Fiber N free extract	8.7% 17.0% 61.0%	1 ton per acre
9.	Check	.....		

Telone was diluted one plus four with kerosene for application. Vapam was used indiluted. DD was diluted one plus five with kerosene. Nemagon was diluted one plus four with kerosene. All tractor injected materials were applied at the four-inch depth. MC-2 was applied under plastic cover, using one pound cans and regular application equipment. Mylone was diluted with fine sand and applied with a hand spreader. After application, the material was mixed into the soil to a depth of three inches with a tandem disc. Molasses-pulp pellets were ground fine and hand broadcast without dilution. This also was disced into the soil to a depth of three inches.

Those plots which received injection with the tractor and diamond point rig were dragged to seal the soil surface. Chloropicrin injection holes were sealed by the heel of the operator's shoe.

Most applications were made May 1, 1957. From application time until planting time, 1.28 inches of rain fell. Mylone and pellet treatments were applied May 10, receiving 0.88 inch of rain afterwards. Soil temperatures at the four-inch depth from May 1 until planting averaged 43° Fahrenheit.

The site chosen for the experiment was in a field which had been in sugar beets for six continuous years and has a history of nematode infestation and *Rhizoctonia* root rot. Soil type is Rocky Ford clay loam. The plots were planted May 29, with variety HH-1.

The plots were set up as randomized blocks with four replications. Plot size was four rows (22 inches) wide by twenty-five feet long.

Results

Observations of emergence vigor and stand showed no differences between treatments. Data taken during the growing season are shown in Table 2. It is assumed that a sufficient interval elapsed between time of application and planting to dissipate any harmful residual effects of the chemicals used.

Later during the growing season, estimations of vigor and stand counts seemed to indicate a favorable response from chloropicrin and methyl bromide. An unfavorable response, viewing stand, was shown by molasses-pulp pellets, Vapam, Telone and DD.

Reductions in stand were caused mainly by *Rhizoctonia* root rot. This disease was noticeably more prevalent in the molasses-pulp pellet treatment. Perhaps the inclusion of this high energy material into the soil promoted the growth of the organisms which caused the root rot. Of course, this was the opposite of the desired effect, but if such be the case, the material might be of use in promoting root rot for reasons of selection for resistant or tolerant plants.

Table 2.—Observations on Sugar Beets Throughout the Growing Season on Soil Treated Plots.

Treatment	July 17, 1957		August 8, 1957
	Vigor	Stand	Stand
Chloropicrin	1.6	98.8	72.2
Telone	3.0	91.2	68.8
Methyl Bromide	1.0	107.8	95.8
Mylone	3.0	100.8	82.0
Vapam	3.2	92.5	62.3
DD	3.0	88.0	57.0
Nemagon	3.5	97.6	72.5
Pellets	3.2	97.0	62.0
Check	3.2	92.8	71.2
Calculated "F"	5.72[1]	2.86[1]	4.36[1]
General Mean	2.74	96.2	71.5
LSD .05	1.00	10.06	16.02
LSD .01	1.32	13.46	21.44
SEM/GM (%)	12.5	3.6	7.8

[1] Significant at 1% level.

Vigor range 1-5, one most vigorous.

Stands are as numbers of beets per 100 feet of row.

To a considerable extent, harvest data (Table 3) confirmed the observations made during the growing season with the exception of Telone. Growing season observations indicated this material to be having a deleterious effect, but this was not substantiated by harvest data, since it did not differ significantly from the check in any attribute measured.

Table 3.—Harvest Performance of Sugar Beets on Soil Treated Plots.

Treatment	Gross Sugar	Percent Sugar	Weight Roots	Number Roots
Chloropicrin	3070	13.6	11.30	55.0
Telone	2860	15.1	9.42	58.2
Methyl Bromide	4794	14.7	16.24	88.5
Mylone	2816	15.2	9.18	73.8
Vapam	1464	14.1	5.06	36.8
DD	1706	15.0	5.65	38.0
Nemagon	2730	14.8	9.10	61.5
Pellets	1796	15.0	5.85	49.8
Check	2704	14.6	9.26	62.2
Calc. "F" for Treatments	8.80[1]	NS	21.36[1]	6.24[1]
General Mean	2660	14.67	9.02	58.19
LSD .05	976	NS	2.17	19.1
LSD .01	1323	NS	2.94	25.9
SEM/GM (%)	12.6	22.3	8.04	11.2

[1] Significant at the 1% level.

Gross Sugar as pounds per acre. Weight of Roots as tons per acre.

Number of Roots as number per 100 feet of row.

Conclusions

None of the materials tested gave satisfactory control of the combination of late season root rot and nematodes except methyl bromide. This material is too expensive for practical use on sugar beets, but serves as a check providing good control.

Results of Divergent Selection for General Combining Ability[1]

D. F. Peterson and D. D. Dickenson

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The red-marker beet has been used as a top-cross parent to identify lines high in general combining ability. (1, 2)[2] Use of the red-marker beet as a tester for general combining ability is desirable in that large numbers of lines may be top crossed in one isolation, thus reducing costs of top-cross seed production and, at the same time, increasing the number of lines that can be handled. In addition, these top-cross hybrids are easily distinguished from other crosses and selfs by plant color, thus insuring stands completely of top-cross origin in the progeny testing program.

If the red-marker beet used as a top-cross tester is effective in identifying lines high in general combining ability, then those lines should be superior combiners, on the average, in specific crosses with male sterile lines, also selected as being high general combiners.

This paper reports a study of eight lines selected for either high or low general combining ability by use of the red-marker beet, and the subsequent performance of these lines when used in single crosses with three male-sterile lines. Based on data from other variety tests, two of these male-sterile lines were considered to be high and one intermediate in general combining ability. Tests for their general combining ability with the red-marker beet are not available, however.

Materials and Methods

In 1954 about 250 roots of the red-marker beet were planted in an isolation in alternate rows with 250 roots of MW 391. Approximately half of the flowering branches of each MW 391 plant were bagged for self-pollinated seed production. Flowers on the remaining half of each MW 391 plant were allowed to open pollinate with the red-marker beet.

In 1955 the S_1 seed produced by bagging in 1954 was planted in the inbred line nursery for root production. Sufficient top-cross seed for testing was obtained from 141 of the 250 MW 391 plants. These top crosses were tested at Sheridan, Wyoming, in a triple lattice design with three replications in single-row plots 50 feet long. From this test, four high-combining lines and four low-combining lines were selected for further study.

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[1] Plant Breeder, Holly Sugar Corporation, Sheridan, Wyoming, and Plant Breeder and Pathologist, Holly Sugar Corporation, Tracy, California, respectively.

[2] Numbers in parentheses refer to literature cited.

The S_1 roots produced in 1955 of each of the eight lines selected were used as pollinators in eight isolations planted at Sheridan, Wyoming, in 1956. Also included in each isolation were 100 roots of each of three male-sterile lines: 5152-01, CT9MS and SL34.611HO.[3] The first two lines were considered to be high and the third intermediate in general combining ability. The male-sterile lines were rogued to eliminate pollinators where necessary and three lots of single cross seed were harvested from each of the eight isolations, making a total of twenty-four single crosses produced.

In 1957 these twenty-four single crosses, the eleven parental lines and one commercial check were tested at Sheridan, Wyoming, and Sidney, Montana. A triple lattice design with six replications was used in testing this material. Plot size was one row, 35 feet long. The entire plot was harvested for weight and sucrose analyses.

Experimental Results

Table 1 presents yield data of the eight red-marker beet top crosses, together with the average single cross yields of the same eight lines when crossed to the three male-sterile lines, 5152-01, CT9MS and SL34.611HO.

Table 1.—Yield of Top Crosses and Average Yield of Single Crosses of Four High-and Four Low-Combining Lines as Measured by Top Crosses with the Red-Marker Beet.

	Beet Yield in Tons Per Acre	
High Lines	**Top Cross[1]**	**Single Cross[2]**
2	24.643	19.446
3	24.061	18.609
4	24.688	19.098
5	23.706	17.133
Ave.	24.274	18.567
Low Lines		
6	18.244	16.616
7	17.492	16.769
8	17.760	17.233
9	15.649	17.118
Ave.	17.286	16.934
LSD 5%	2.969	1.789
Check (MW 391)	21.365	17.444

[1] Data from 1955 test at Sheridan, Wyoming.
[2] Data from 1957 tests at Sheridan, Wyoming, and Sidney, Montana.

[3] CT9MS and SL34.611HO were developed at the U. S. Department of Agriculture Field Station at Salt Lake City by Dr. F. V. Owen and Dr. V. F. Savitsky, respectively.

It is readily apparent that the tonnage figures for the four high combining top crosses are significantly greater than those for the four low combining top crosses. It was also found that the average single cross yields are closely associated with the top-cross yields as indicated by the correlation coefficient of .79, significant at the 5 percent level. The mean value of all single crosses involving high-combining lines was 18.567 tons per acre, and the mean value of all single crosses involving low-combining lines was 16.934 tons per acre. This difference is significant at odds of 99:1 as calculated by the t test for significance.

These data indicate that on the average the four lines selected as high combiners are significantly better combiners in regard to tonnage than the four lines selected as low combiners.

Average tons per acre for all single crosses was 17.750 tons, whereas average tons per acre for the pollinator lines was 13.695 tons, and average tons per acre for the male-sterile lines was 12.849 tons, indicating heterosis for yield in these crosses.

In addition, several single crosses in the high-combining group were significantly greater in tons of beets per acre when compared to the commercial check.

Table 2 gives the sucrose percentages corresponding to yields given in Table 1.

Table 2.—Percent Sucrose of Top Crosses and Average Percent Sucrose of Single Crosses of Four High- and Four Low-Combining Lines as Measured by Top Crosses with the Red-Marker Beet.

	Percent Sucrose	
High Lines	**Top Cross[1]**	**Single Cross[2]**
2	12.76	15.05
3	12.26	14.56
4	12.60	14.47
5	12.80	14.33
Ave.	12.60	14.60
Low Lnes		
6	12.94	15.20
7	13.12	14.73
8	13.16	15.01
9	12.63	14.81
Ave.	12.96	14.94
LSD 5%	.62	.52
Check (MW 391)	15.72	14.48

[1] Data from 1955 test at Sheridan, Wyoming.
[2] Data from 1957 tests at Sheridan, Wyoming, and Sidney, Montana.

Very little emphasis was placed on percent sucrose in selecting the high- and low-combining lines. The difference in means between high and low top-cross groups is not significant on the basis of the four comparisons tested. The relationship between the percent sucrose of the top crosses and the average percent sucrose of the single crosses was weak as indicated by the correlation value of .46. The mean value, 14.60 percent sucrose, of all single crosses involving high-combining lines was significantly less than the mean value, 14.94 percent sucrose, of all single crosses involving low-combining lines at odds of 99:1 as calculated by the t test.

Data from this table indicate that on the average lines selected for high general combining ability by the red-marker beet, with little emphasis placed on sucrose, will produce single crosses lower in percent sucrose than lines selected for low general combining ability.

A further study of the percent sucrose for four of the single crosses is set forth in Table 3.

Table 3.—Percent Sucrose of Four Selected Single Crosses Together with Percent Sucrose of the Parents and Parental Means.

Single Cross		Percent Sucrose			
No.	Pedigree	P_1	P_2	F_1	$\frac{P_1 + P_2}{2}$
1	5152-01 x 6112-0	14.56	14.23	15.28	14.40
2	CT9MS x 6112-0	14.38	14.23	14.92	14.31
3	5152-01 x 6113-0	14.56	13.75	14.70	14.16
4	CT9MS x 6114-0	14.38	13.56	14.48	13.97
	LSD at 5% level = .52				

It is interesting to note that single crosses 1 and 2 showed heterosis for percent sucrose in that the sucrose contents of the F_1 hybrids were significantly greater than the sucrose content of the higher parent. Single crosses 3 and 4 exhibited dominance for percent sucrose in that the sucrose content of the F_1 hybrid was significantly greater than the average sucrose content of the two parents.

Average percent sucrose for all single crosses was 14.78 percent, whereas percent sucrose for the pollinator lines was 14.40 percent, and average percent sucrose for the three male-sterile lines was 14.68 percent. Although these differences are not significant, it is interesting to note that the single crosses show a greater percent sucrose than either parent, rather than an intermediate value.

It was also observed that the four single crosses showing heterosis or dominance for percent sucrose had as their pollinators, lines from the high-combining group.

Several single crosses, especially those showing heterosis and dominance for sucrose, had a significantly higher percent sucrose than the commercial check.

In Table 4 is given the sugar per acre yields corresponding to yields and sucrose percentages given in Tables 1 and 2.

Table 4.—Sugar Per Acre Yields of Top Crosses and Average Sugar Per Acre Yields of Single Crosses of Four High- and Four Low-combining Lines as Measured by the Top Crosses with the Red-Marker Beet.

	Pounds Sugar Per Acre	
High Lines	**Top Cross[1]**	**Single Cross[2]**
2	6289	5854
3	5900	5414
4	6221	5522
5	6069	4909
Ave.	6120	5426
Low Lines		
6	4722	5049
7	4590	4941
8	4674	5172
9	3853	5072
Ave.	4485	5059
LSD 5%	813	552
Check (MW 391)	6716	5052

[1] Data from 1955 test at Sheridan, Wyoming.
[2] Data from 1957 tests at Sheridan, Wyoming, and Sidney, Montana.

It is quite apparent that the top-cross sugar per acre yields of the four high-combining lines are significantly greater than the top-cross sugar per acre yields of the four low-combining lines. This is a reflection of the large spread in tonnage between the two groups of top crosses. The association for sugar per acre between top crosses and average single crosses is intermediate between tons and percent sucrose as shown by the r value of .54 which is not significant at the 5 percent level. The mean value, 5426 pounds sugar per acre, for all single crosses involving high-combining lines is significantly greater than the mean value, 5059 pounds sugar per acre, for all single crosses involving low-combining lines at odds of 98:2 as calculated by the t test for significance.

These data indicate that lines selected as high general combiners by the red-marker beet will, on the average, produce significantly more sugar per acre than lines selected as low general combiners.

It should also be pointed out that several single crosses in the high-combining group produced more sugar per acre than the commercial check.

Summary and Conclusion

As stated before, if the red-marker beet used as a top-cross tester provides good measure of general combining ability, then lines identified by it as superior in general combining ability should produce, on the average, superior hybrids when used in specific single cross combinations.

The data presented in this paper show that on the average single crosses utilizing lines high in general combining ability produced a greater tonnage per acre, a lower percent sucrose, and more sugar per acre than single crosses utilizing lines low in general combining ability.

Certain single crosses were shown to exhibit either heterosis or dominance for percent sucrose and for the material tested, dominance and heterosis were found in single crosses arising from high general combining lines.

The single crosses showing the greatest production of sugar per acre were those whose parents were high in general combining ability when crossed to the red-marker beet and at the same time showed heterosis for percent sucrose.

Literature Cited

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Sugar Beet Production in Michigan as Affected by Cropping Sequence and Fertility Level[1]

J. R. Guttay, R. L. Cook and L. S. Robertson[2]

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The concept of cropping systems that evolved from early research on cropping sequence and rotations is changing. Improved technology has minimized the values previously placed on several rotational effects. The use of legume sod crops, once thought of as necessary to lasting crop production, has been reduced in importance owing to increased supplies of low-cost commercial nitrogen. Disease resistant crop varieties and improved pesticides have decreased the need of rotational control of some soil-borne pathogens. Mechanization has reduced the necessity of labor distribution afforded by rotations and increased the economy in specialization. The net effect of these developments is to lessen the need of producing soil building sod crops, particularly on the more productive soils. In lieu of these facts, it is important to have an evaluation of the effects of less sod and more intensive cropping systems on the subsequent production of specific crops. Data evaluating the effect of various cropping systems on the production of sugar beets in Michigan is presented in this report.

Experimental Methods

An experiment was initiated in 1941, to study the effects of seven different cropping sequences on the production of sugar beets. In 1951, another experiment adjacent to the older experiment involving six new sequences was established. The soil type was predominantly a Sims clay loam with associated minor types of the same soil management group. The two experiments, while being in the immediate vicinity of one another, will be discussed as separate studies owing to the differences in length of time established and in previous management history. The experiment was originated to answer certain questions regarding differential cropping sequence in the production of sugar beets. Of particular interest was the effects that legumes might have on the sugar beet yields. Accordingly, alfalfa and the clovers are important rotational constituents in the study.

The experiment was designed so that all crops in any one rotation appear each year. The plots are divided into high and low fertility sub-plots and are replicated four times. A more detailed description of the plot layout and design established

[1] Contribution from the Soil Science Department, Michigan Agricultural Experiment Station, East Lansing, Mich. Journal Article 2201.

[2] Soil Science Department, Michigan Agricultural Experiment Station, East Lansing, Michigan.

in 1941 are published (1)[3]. The plot layout and design of the new rotations, established in 1951, are similar to these.

In 1951, after 10 years of operation, changes were made in some of the experimental treatments. From 1941 to 1950, one sub-plot of each rotational plot had received 400 pounds of 2-16-8 fertilizer per rotation (five years) and the other sub-plot received 1000 pounds. One-half of the fertilizer was applied to sugar beets and the remainder divided among the row and grain crops in the rotation. In 1951, the treatments on the sub-plot receiving the 400 pounds of fertilizer per rotation was changed to 2000 pounds of 4-16-8. The new rotations had a fertilizer program similar to this changed program for the old rotations. The sub-plots were further divided into two sub-plots, one of which received supplemental nitrogen on all cash crops. Alfalfa-brome hay was substituted for clover-timothy hay in rotation 5 listed below because clover-timothy is not a recommended forage for this area in Michigan, and crop yields were shown to be lower than where alfalfa-brome was used.

The rotations included in both experiments are as follows:

1. Alfalfa-brome hay, alfalfa-brome hay, corn, sugar beets, barley.
2. Alfalfa-brome hay, alfalfa-brome hay, sugar beets, corn, barley.
3. Alfalfa-brome hay, alfalfa-brome hay, white pea beans, sugar beets, barley.
4. Alfalfa-brome hay, corn, sugar beets, barley, oats.
5. Alfalfa-brome hay, alfalfa-brome (plowed down), sugar beets, corn, barley[4].
6. White pea beans, wheat, corn, sugar beets, barley.
7. White pea beans, wheat (green manure[5]), corn, (sweet clover), sugar beets, barley (green manure[5]).
8. Alfalfa-brome hay, alfalfa-brome hay, corn, sugar beets, barley.
9. Alfalfa-brome hay, alfalfa-brome (plowed down), corn, (sweet clover), sugar beets, barley[4].
10. Alfalfa-brome hay, alfalfa-brome (plowed down), sugar beets, corn (sweet clover), barley[4].
11. Alfalfa-brome hay, corn (sweet clover), sugar beets, oats (green manure[5]), barley[4].
12. White pea beans, wheat, sweet clover (plowed down), sugar beets, barley (green manure[5]).
13. White pea beans, wheat, sweet clover seed, sugar beets, barley (green manure[5])[4].

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[3] Numbers in parentheses refer to literature cited.
[4] Rotations 5 and 8-13 were started in 1951, the rest started in 1941.
[5] Green manure refers to a mixture of equal parts of mammoth, June, alsike and sweet clovers seeded at a rate of 12 pounds/ac.

Experimental Results

Old Rotations

The weather during the last seven years varied greatly between years. The wettest year of the entire 17-year study occurred in 1957, and the dryest year in 1955. The yields of the old rotations for these two years, as shown in Table 1, are likewise contrasting with the highest yields of the entire study occurring in 1955, and the lowest yield of the last seven years in 1957. Generally, the yields of beets from 1951 to 1957 were approximately two tons per acre higher than during the previous 10 years. This comparison can be made only at the low level of fertilization where fertilizer rate was constant over the entire period. The average yield for each rotation for the entire 17-year period can likewise be made only at the low level of fertilization for the

Table 1.—The Yield of Sugar Beets as Affected by Cropping System and Fertilizer Application.

Rotation and Level	Tons per Acre								Rotation Mean	Yield Increase With N	1941-1957 Mean
	1951	1952	1953	1954	1955	1956	1957	Mean			
1 H	13.6	12.2	15.2	17.9	21.1	10.8	8.6	14.2	13.6	0.0	
1 L	12.9	12.0	14.4	15.0	20.3	10.0	6.3	13.0			11.7
2 H	14.3	11.9	13.4	14.6	20.0	10.7	7.2	13.2	12.9	—0.6	
2 L	14.7	12.0	11.9	12.8	18.7	11.1	6.8	12.6			11.5
3 H	15.4	13.9	16.2	16.8	22.3	12.0	9.9	15.2	14.4	—0.4	
3 L	14.6	11.7	13.6	15.6	21.3	11.0	6.7	13.5			12.3
4 H	11.1	12.7	16.4	15.9	22.9	10.3	8.2	13.9	13.6	0.4	
4 L	12.7	13.1	15.3	14.0	20.8	10.6	6.7	13.3			12.0
5 H	8.5	11.0	14.2	8.6	22.0	9.5	9.5	11.9	11.6	0.1	
5 L	8.3	11.3	13.5	8.8	20.5	8.8	7.9	11.3			
6 H	9.0	11.9	14.0	15.0	20.4	10.0	7.2	12.5	12.0	0.9	
6 L	9.4	11.3	13.3	13.0	19.3	8.5	6.2	11.6			10.5
7 H	9.6	13.1	14.3	15.8	22.0	10.8	84	13.4	13.2	0.7	
7 L	10.8	12.8	14.6	13.3	21.1	10.2	7.3	12.9			11.6
L.S.D. 5% between rotations at each level	1.7	1.8	1.4	1.4	1.9	1.6	1.6	0.5	0.5		0.4
L.S.D. 5% within rotations	1.0	1.5	1.3	1.0	1.3	.8	.9	0.3		0.5	

same reason. The average yields for all periods fall into a rather consistent pattern with little interaction between periods and rotations. The general results and conclusions of earlier progress reports (6) (3) are still valid in regard to crop sequence effect.

During the last seven years, the following results have occurred:

1. The highest average beet yields have been obtained where beets have followed white pea beans in rotations with two years of alfalfa-brome hay preceding the beans (rotation 3).

2. The beet yields where corn, instead of beans, has been the intervening crop between the alfalfa and sugar beets (rotation 1, 4) have averaged 0.8 ton less.

3. The lowest beet yields occurred where beets followed second year alfalfa-brome hay that had not been harvested the second year (rotation 5). Where the alfalfa-brome was harvested as hay (rotation 2) the beet yields averaged 1.3 tons more than where it was plowed down, but these yields were still 0.7 ton under those obtained from beets in alfalfa rotations with an intervening corn crop.

4. Beets grown after corn that had been seeded to a green manure crop (rotation 7), have yielded 0.4 ton below those obtained from beets after corn in the alfalfa rotations 1 and 4. Nitrogen sidedressing increased the beet yields in rotation 7 to where they were equal to 1 and 4.

5. Beets after corn without green manure of alfalfa (rotation 6) have yielded 0.8 of a ton less than where green manure was seeded. Forty pounds of nitrogen sidedressed to these beets increased the yield nearly equivalent to that where a green manure crop appeared in the rotation.

6. Nitrogen sidedressing on beets in rotations having an alfalfa sod within two years of beet planting has not produced a significant yield increase and has produced a decrease in yield where alfalfa has immediately preceded beets. Yield decreases with nitrogen sidedressing occurred in 1955, with high summer temperatures prevailing. Response of sugar beets to nitrogen sidedressing has previously been shown to be negatively correlated with summer temperature (2).

7. Beets from plots fertilized with 1000 pounds of 4-16-8 per acre have produced yields averaging nearly one ton more than from those receiving 500 pounds. If the last five years are considered, allowing the two years previous as time to reach equilibrium with the new fertilizer rate, then beets from plots at the higher fertilizer rate have averaged 1.3 tons more than those from plots at the lower rate.

Sucrose

The average sucrose percentage of the last seven years did not vary greatly from that previously found. The 1951-1957 averages, as shown in Table 2, compares with the average of the entire period covered by sucrose analysis (1946-1957). Fertilizer level has not had any effect on sucrose analysis and percentages shown are the average over both levels.

Sucrose percentage has been highest in beets produced in non-legume rotations (rotation 6 and 7), and lowest in beets grown after alfalfa (rotations 2 and 5). Beets grown after corn (rotations 1 and 4) or beans (rotation 3) in rotations with alfalfa had sucrose percentages intermediate between the extremes.

Table 2.—The Average Percent Sucrose and Gross Sugar Produced as Affected by Cropping System and Nitrogen Sidedressing.

	% Sucrose		Pounds Gross Sugar/Acre at the High Fertilizer Level (1951-1957)		
Rotation	1951-1957	1946-1957		With Addition N	Net Change
1	17.9	17.9	5084	4970	—114
2	17.2	17.2	4540	4233	—307
3	18.0	18.0	5472	5209	—263
4	18.3	18.2	5088	5119	+31
5	17.2		4094	4032	—62
6	18.7	18.6	4676	4904	+228
7	18.4	18.4	4932	5076	+144
L.S.D. 5% between rotation means	0.4	0.4			

The values in Table 2 of gross sugar produced show nearly the same differences between rotations as the yield data with the highest yield of sugar produced occurring in rotations with beets following beans and the lowest yield with beets after alfalfa. Nitrogen sidedressing has not shown any consistent interaction with rotations on sucrose percentage, but has produced an average decrease of 0.4 percent in sucrose over all rotations. The increase in yield attributed to nitrogen in rotations 4, 6 and 7 more than offsets this reduction in sugar percent and the gross sugar produced was increased. In the other systems, the gross sugar was reduced by nitrogen sidedressing.

Yearly Variability

The variability of both yield of sugar beets and percent sucrose was greater between years than between treatments within years. The average beet yield and sucrose percentage over all

rotations in the older experiment, the number of days between planting and harvest, and modifying climatological data for the last seven years are given in Table 3. The yearly variability of beet yields has been attributed, at least in part, to early summer precipitation (5). The average yields from 1945 to 1957 show a highly significant correlation coefficient of r = — .826 with total precipitation occurring in April, May, June, and July. The two years of high sucrose percentage, 1952 and 1953 have in common the weather conditions of an average early summer precipitation and a dry season prior to harvest. The only year of high sucrose percentages prior to this was in 1946, with an average sucrose content of 19.5%. The year, 1946, as 1952 and 1953, was characterized by average early summer precipitation (10.0 inches) and low precipitation prior to harvest (1.7 inches).

Table 3.—The Average Beet Yield and Percent Sucrose, Growing Season, and Climatological Data Over All Rotations in the Older Experiment for 1951-1957.

	Year						
	1951	1952	1953	1954	1955	1956	1957
Avg. yield, tons/acre	12.5	12.3	14.1	14.0	20.3	10.4	8.0
Avg. sucrose percent	16.6	20.2	21.3	15.8	17.9	17.3	16.4
No. of days from planting to harvest	165	174	165	174	185	138	162
Precipitation, inches							
April, May, June, July	9.9	9.5	11.5	10.5	7.8	19.9	21.6
30 days prior to harvest	4.9	0.4	1.6	3.5	3.1	0.5	2.7
Temperature, No. of days with Maximums over 90°, June and July	8	22	11	12	31	3	6
Minimums under 32°, 30 days prior to harvest	9	15	4	9	5	5	4

The temperature data do not correlate as well as precipitation with the best yields and sucrose percentages, although high temperature appears to be associated with a dry climate and, conversely, a low temperature with wet climate. Temperature effects are important, however, in affecting response to beets to nitrogen sidedressing as shown previously (2).

New Rotations

The yields of sugar beets in the new rotations have averaged higher the last seven years than in the old rotations. This is shown by comparing rotations 1 and 8 on the two areas. The new rotations were established on an adjacent area, of similar soil type, to the old rotations, but the two areas are not com-

parable. It is believed that previous historical differences in ownership and management are responsible, in part, for the difference. The yield data for the new rotations are given in Table 4.

Table 4.—The Yield of Sugar Beets as Affected by Cropping System and Fertilizer Application.

Rotation and Level	Tons per Acre								Rotation Mean	Yield Increase with N
	1951	1952	1953	1954	1955	1956	1957	Mean		
8 H	14.7	13.7	17.9	19.1	20.2	13.1	14.1	16.1	15.5	.2
8 L	14.3	12.4	16.4	18.1	18.4	12.8	12.1	14.9		
9 H	14.9	14.2	16.0	18.4	22.0	11.6	12.0	15.6	15.1	.5
9 L	14.9	12.8	14.1	18.4	20.8	12.0	9.8	14.7		
10 H	15.6	16.7	14.6	16.1	19.6	12.8	14.3	15.7	15.3	—.6
10 L	14.8	16.8	14.6	16.9	18.8	11.1	12.0	15.0		
11 H	15.1	13.7	15.0	17.1	21.1	14.3	13.6	15.7	15.5	.4
11 L	15.3	15.3	14.5	17.4	21.0	13.2	11.7	15.2		
12 H	16.7	17.1	15.2	17.1	21.8	12.9	17.5	16.9	16.5	.0
12 L	16.1	16.1	14.4	17.1	21.2	13.1	14.7	16.1		
13 H	15.7	16.9	13.4	17.8	19.3	12.8	14.4	15.8	15.4	.0
13 L	15.2	15.8	12.8	17.3	20.1	12.4	12.3	15.1		
L.S.D. 5% between rotations at each level	1.9	2.3	1.4	2.6	2.7	1.9	2.0	0.6	0.6	
L.S.D. 5% within rotations	1.8	1.0	0.9	2.0	1.6	1.3	1.5	0.4		0.7

The yield difference between rotation 12, where sugar beets followed sweet clover plowed down in full blossom in August and seeded to an oats cover crop, and the other systems is significant. The plowing down of sweet clover has been shown to give benefits to beet yields only when immediately preceding the sugar beets in sequence (4).

The beneficial effects of plowed down sweet clover are mostly dissipated after one year. Plowing down sweet clover ahead of sugar beets has averaged over a ton more than where the sweet clover is harvested for seed. As occurred in the older experiment, planting sugar beets after alfalfa resulted in the lowest yield.

Nitrogen sidedressing has increased yields slightly where beets follow corn and produced a decrease in yield where beets follow alfalfa. The fertilizer response has been of the same magnitude as in the older experiment.

Table 5.—The Average Percent Sucrose and Gross Sugar Produced as Affected by Cropping System and Nitrogen Sidedressing.

		Pounds Gross Sugar/Acre at the High Fertilizer Level		
Rotation	**% Sucrose**		**With Additional N**	**Net Change**
8	18.4	5925	5835	—90
9	18.7	5834	5860	+26
10	17.9	5621	5255	—366
11	18.8	5903	5893	—10
12	19.0	6422	6253	—169
13	19.0	6004	5846	—158
L.S.D. 5% between rotation means	0.2			

Sucrose percentages for beets grown in these rotations are shown in Table 5. The fertilizer rate has not been significant in affecting sucrose percent and the percentages given are of an average over both levels. Sugar beets after a year of sweet clover (rotations 12, 13) averaged the highest percent sucrose and except for the first year, had the highest yearly percent. This high percent sucrose, coupled with the high yield, particularly where the sweet clover was plowed down, places this rotation first in quantity of gross sugar produced. The lowest yield of gross sugar occurred where sugar beets followed alfalfa.

Nitrogen sidedressing, on the average, decreased sucrose percentage to about the same extent as occurred in the old experiment, 0.5%. The decrease in sucrose percent was not compensated for by a sufficient yield increase, so that, in general less sugar has been produced where additional nitrogen fertilizer was used. A substantial loss in yield of sugar was noted where nitrogen was applied to beets following alfalfa.

Summary

Two cropping system experiments, one established in 1941 and the other in 1951, and comprising 12 different cropping systems have been carried out in Michigan. One of these rotations is common to both experiments. The effects of rotation on yield and sugar content of sugar beets have been studied, together with the interaction of these systems with two fertilizer rates and supplemental nitrogen.

The data may be summarized as follows:

In cropping systems with alfalfa sod, on soils similar to that involved in these experiments:

1. Sugar beets should not follow alfalfa in rotation, owing to the possibility of a depression in both yield of roots and percent sucrose.

2. Sugar beets should be planted after an intervening crop of white pea beans or corn following the alfalfa with the best sequence, beets after beans.

3. The cropping system of 20 percent is as effective in producing high yields as one with 40 percent sod.

4. A nitrogen sidedressing should not be used on sugar beets, if beets are planted two years or less after a good alfalfa sod is turned under.

In cropping systems without alfalfa:

1. Highest yields of sugar beets are obtained where they follow a sweet clover crop. The best yields of beets occurred where spring seeded sweet clover is plowed down at full blossom the year before sugar beets are planted.

2. Sweet clover harvested for seed the year before beets are planted diminishes the yield benefit from that occurring from plowing it down, but results will still be as good as in alfalfa systems where beets follow corn.

3. Sweet clover seeded in corn ahead of beets does not benefit yields as much as results from having sweet clover come to maturity as previously described, but it will benefit yields sufficiently to pay for the seeding.

4. Nitrogen sidedressing increases yield of beets where sweet clover seedings were not made the year before sugar beets and also where seedings were made in corn. Sugar beets planted after corn with the seeding and with the nitrogen sidedressing, yield just as well as in alfalfa rotations with beets following corn.

In all cropping systems:

1. The difference in yield between the beets produced at the high fertilizer rate (1000 pounds/acre of 4-16-8) and the low rate (500 pounds/acre of 4-16-8) is marginal (1.0 - 1.3 tons/acre) in respect to profitable use of fertilizer at today's market value. The most effective rate is probably between the two rates used and will vary according to the varying price of beets and fertilizer.

2. Alfalfa sod is not necessary to have high beet yields. Assiduous use of sweet clover and nitrogen fertilizer eliminates the necessity of alfalfa sod as a soil conditioner on these soils.

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Studies of Chemical Treatments on Sugar Beets Including Gibberellic Acid, 2,4-D, and Maleic Hydrazide

R. T. NELSON AND R. R. WOOD[1,2]

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To increase plant growth by supplements other than fertilizers has been an objective for many years. In the last decade there has been an increasing number of chemicals for testing. Chemicals that would increase the root yield, sugar content, or storage quality of sugar beets would have a definite place in sugar beet culture along with the fertilizers, fungicides, and insecticides already so effectively used. Many reports have been published demonstrating increased size of plants of various species following treatment with gibberellic acid. There has been indication from some previous tests that 2,4-D and some of its derivatives favorably influenced top to root ratio and root yields of sugar beets. Similarly, various investigators working with maleic hydrazide have sometimes shown a decrease in storage losses for beets treated versus beets not treated.

Since it became evident during the summer of 1957 that enough gibberellic acid would be available for field trials on sugar beets, a test including the three materials was initiated. The field test area selected was above average in level of fertility and represented good soil uniformity and was planted with commercial variety GW359. Plots were six rows wide and 23 feet in length. The width between rows was 22 inches. The test consisted of eight treatments in a randomized complete block design and six replications. For the evaluation of yield, six rows x 18 feet were harvested per plot. Two of the six rows were used for sugar and quality determinations and only one row for respiration evaluations.

All treatments were made either September 3 or September 24. The beet tops were covering the ground at these dates; thus, all walking was confined to the margins of the plots. Treatments were applied with a knapsack sprayer fitted with a flat fan *TeeJet* nozzle. The gibberellic acid was prepared for use by dissolving one gram in 100 ml. of 95 percent ethyl alcohol saturated with sodium bicarbonate. This concentrate was diluted with water just before spraying to make solutions 10 and 100 p.p.m. gibberellic acid equivalent. The 2,4-D and maleic hydra-

[1] Agronomists, Agricultural Experiment Station, The Great Western Sugar Company, Longmont, Colorado.

[2] The authors especially wish to thank Eli Lilly and Company for contributing the gibberellic acid used in this test.

zide were diluted with water directly from commercial formulations. The volume of spray used was in each case a rate of 100 gallons per acre.

The harvesting, laboratory, and statistical analysis were carried out in accordance with standard methods. The respiration rate was evaluated on transverse sections from 14 beet roots per plot in accordance with methods previously described (1)[3]. Beets in the test were harvested October 15. Roots required for evaluation of respiration rate were stored in a cool, moist root cellar from October 15 to November 1, at which time respiration rate determinations were made.

The treatments and results appear in Tables 1, 2, and 3.

Table 1.—Number and Description of Treatments Used.

Tr. No.	Description
1.	Gibberellic acid 10 p.p.m. aqueous solution at 100 gallons per acre applied six weeks before harvest.
2.	Gibberellic acid 100 p.p.m. aqueous solution at 100 gallons per acre applied six weeks before harvest.
3.	Gibberellic acid 10 p.p.m. aqueous solution at 100 gallons per acre applied three weeks before harvest.
4.	Gibberellic acid 100 p.p.m. aqueous solution at 100 gallons per acre applied three weeks before harvest.
5.	Esteron 2,4-D at 30 p.p.m. acid equivalent in aqueous solution applied at 100 gallons per acre six weeks before harvest.
6.	Active ingredients of treatment 2 and treatment 5 applied in 100 gallons water per acre six weeks before harvest.
7.	Maleic hydrazide 1000 p.p.m. aqueous solution at 100 gallons per acre applied three weeks before harvest.
8.	Check, no active ingredient and no water.

A generalization of the results in Table 2 indicates that as the yield increased, the sugar percentage tended to be lower. Treatment 1 was an exception in which case the yield improved significantly without a reduction in sugar percentage. This would suggest that in planning future studies earlier applications should be considered, especially if quantities higher than represented by the 10 p.p.m. treatment of gibberellic acid is to be used. The 10 p.p.m. solution at 100 gallons per acre approximates 3.78 grams or one-eighth ounce of gibberellic acid per acre.

The differences in this test caused by 2,4-D and maleic hydrazide were negligible. The effect of 2,4-D appeared negligible whether used alone or in combination with gibberellic acid. The thin juice purity results for this test appear irregular. In contrast, the yield and sugar percentages parallel the quantity

[3] Numbers in parentheses refer to literature cited.

Table 2.—Harvest Results on Sugar Beets Receiving Foliar Treatment Three or Six Weeks Before Harvest.

Treatment	Beets per 100 Feet	Beets Per Acre	Sugar Content	Sugar Per Acre	Thin Juice Purity
		Tons	Percent	Pounds	Percent
1) 10 p.p.m. Gib., Sept. 3	106	28.2[1]	14.5	8181[1]	89.9
2) 100 p.p.m. Gib., Sept. 3	106	29.8[1]	12.3[2]	7338	86.4[2]
3) 10 p.p.m. Gib., Sept. 24	105	27.7[1]	13.7	7606	88.2
4) 100 p.p.m. Gib., Sept. 24	105	28.0[1]	13.1[2]	7318	89.0
5) 30 p.p.m. 2,4-D, Sept. 3	107	26.3	13.6	7140	86.5[2]
6) 100 p.p.m. Gib., +30 p.p.m. 2,4-D, Sept. 3	106	29.7[1]	12.3[2]	7304	87.9
7) 1000 p.p.m. MH, Sept. 24	106	26.3	14.3	7519	86.9
8) Check	103	26.2	14.1	7381	88.9
LSD 5% pt.	——	1.5	0.9	638	2.3
LSD 1% pt.	——	2.0	1.2	856	NS

[1]Significantly higher than check.
[2]Significantly lower than check.
NS—Not significant.

Table 3.—Sodium and Potassium Content of Beet Roots and Respiration Rate as Carbon Dioxide Evolved Per Kilogram Sliced Tissue Per Hour at 70° F.

Treatment	Na on Beets	K on Beets	Respiration as CO_2
	Percent	Percent	Milligrams
1) 10 p.p.m. Gib., Sept. 3	.14	.20	201
2) 100 p.p.m. Gib., Sept. 3	.21	.20	203
3) 10 p.p.m. Gib., Sept 24	.17	.20	200
4) 100 p.p.m. Gib., Sept. 24	.16	.18	198
5) 30 p.p.m. 2,4-D, Sept. 3	.19	.20	207
6) 100 p.p.m. Gib. +30 p.p.m. 2,4-D, Sept. 3	.17	.18	192
7) 1000 p.p.m. MH, Sept. 24	.17	.21	202
8) Check	.16	.18	209
LSD 5% pt.	NS	.018	NS
LSD 1% pt.	NS	.024	NS

NS—Not significant.

of gibberellic acid used and an assumed eflect time of application might play. Aside from the decrease in sugar percentage shown in Table 2, it was not apparent that the treatments had any adverse effects on the crop.

Summary

An increase in yield of marketable sugar beet roots was obtained from field plots receiving foliar applications of gibberellic acid three or six weeks prior to harvest. Two rates, namely, 10 and 100 p.p.m. gibberellic acid solutions each at 100 gallons per acre were tested. The 100 p.p.m. rate decreased the sugar percentage sufficiently to cancel any gain in sugar production even though the root yield represented a gain of 1.8 to 3.6 tons per acre. The 10 p.p.m. rate, however, did not show a significant change in sugar percentage and in the treatment applied six weeks before harvest showed in this test a root yield increase which was significant at the 1 percent level and a sugar production increase which was significant at the 5 percent level.

In this test there appeared to be no yield response to 2,4-D application whether applied alone or in combination with gibberellic acid. Similarly, there was no yield response from maleic hydrazide.

Evaluations of respiration rate of roots following harvest on sliced root sections revealed no significant difference between any of the treatments.

Further studies with gibberellic acid appear warranted since one treatment indicated a 10 percent increase in total pounds sugar compared with the check treatment. If increases of this magnitude can be repeated with reasonable regularity, the use of gibberellins on commercially grown sugar beets would be economically feasible.

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Techniques for Increasing the Efficacy of 1,3-Dichloropropene Soil Fumigants in the Control of the Sugar Beet and Root-Knot Nematodes in Sugar Beets

G. O. TURNER[1]

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The sugar beet nematode, *Heterodera schachtii* (Schmidt), and the root-knot nematodes, *Meloidogyne* spp., are very serious pests of the sugar beet industry. At present, the only effective means of control are crop rotation and soil fumigation.

Soil fumigants containing a mixture of 1,3-dichloropropenes and 1,2-dichloropropane have been used for many years as a control for the sugar beet nematode; however, they have not been used extensively for this purpose except in the Utah-Idaho area. The chief reason for the limited use of soil fumigants in other sugar beet growing areas for nematode control has been cost. The object of the experiments reported in this paper was to evaluate several possible methods of increasing the efficiency of the fumigant in relation to the nematode control and yield obtained.

Although most of the data reported are from experiments for the control of the sugar beet nematode, the principles generally apply to the control of the root-knot and other plant parasitic nematodes.

Methods

All experiments reported were conducted in commercial sugar beet fields grown on sandy loam or loam near Santa Maria, California, and Layton, Utah. These fields had a sugar beet nematode "history," and sugar beets were a part of the rotation program.

All experiments were tractor applied. Telone[2] was injected eight inches below the surface of the soil. Immediately after treatment, the soil was rolled with a loose-ring cultipacker to seal the surface and to break up surface clods. The individual plots were at least four beds wide and 100 feet long. To eliminate border effects, the center 50 feet of the two middle beds were used for determinations of growth and yield. Generally, there was a two-week interval between treatment and seeding. Except where noted, sugar beets were planted two rows per 40-inch beds.

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[1] Field Agriculturalist, The Dow Chemical Co., Seal Beach, California.

[2] Telone, the trademark of The Dow Chemical Company's 1,3-dichloropropene soil fumigant.

Experimental

Influence of Soil Fumigant Placement Relative to the Plant Row Upon Yield.

Experiments for the purpose of investigating the influence of shank placement were conducted in 1956 and 1957 with parallel results. The data from the 1957 experiment are shown in Table 1. The soil in the 1957 experiment was a Yolo loam. When treated, it had a moisture content of 23 percent at 8 inches and an air space percentage of 28. At 18 inches the moisture content was 17 percent and air space 33 percent. Soil temperature was 52° F. at 8 inches. Quadruplicate randomized blocks were used.

Telone was injected into the plant beds using one, two, or three chisels per bed. The three-chisels-per-bed application approximated the fumigant distribution which is obtained with overall (non-bedded) treatment using chisels on 12-inch centers 8 inches deep. In the two-chisels-per-bed treatment the fumigant was applied approximately 8 inches below each future seed row. With the one-chisel-per-bed treatment the fumigant was applied approximately 8 inches below the surface in the middle of the bed.

Table 1.—Effect of Fumigant Placement and Telone Dosage on Sugar Beet Yield (1957).

Fumigant Placement	Telone[1] Gal./Acre	Yield Tons/Acre
Three chisels per bed (12" centers)	15	18.3
	20	18.5
Two chisels per bed (14"-26")	15	21.8
	20	20.4
One chisel per bed	15	19.6
	20	19.7
Untreated	—	12.4
LSD 5%		2.5

[1] Contains over 90% 1,3-dichloropropenes.

Yield from each of the treatments was significantly larger than that from the untreated plots. Yields from the plots with the two-chisels-per-bed application were significantly larger than those from the three-chisels-per-bed treatments at the 15-gallon per acre dosage. The differences between the yield data with one chisel per bed and with two chisels per bed, although apparent, were not quite statistically significant at the 5 percent level.

The Influence of Soil Preparation on the Effectiveness of 1,3-dichloropropene Soil Fumigant.

This experiment was conducted on a Yolo sandy loam soil containing 15 percent water at the 8-inch depth, while soil temperature at this depth was 50° F. A split plot experimental design was used with four replications for both the main plots and the sub plots. Separate areas in the field were chiseled to 12 inches, subsoiled 20 to 24 inches deep or left unworked. The entire experimental area was then disced and bedded.

The two-shank-per-bed method of application was employed. At the time of fumigant application the air space percentages at the 8-inch level were higher after chiseling and discing and after subsoiling and discing than with discing only (Table 2).

Table 2.—Effect of Soil Preparation Prior to Treatment on Sugar Beet Nematode Control as Indicated by Yield.

	Air Space Percentage at 8 Inches	Tons Sugar Beets Per Acre	
		Telone 15 Gal./A.	Untreated
Chiseled and disced	33	22.8	18.0
Subsoiled and disced	31	21.5	17.0
Disced only	23	19.2	18.7
LSD 5%		2.4	

In this experiment, chiseling or subsoiling had no significant effect on the yield of sugar beets without soil fumigation. Telone at 15 gallons per acre gave a slight but not significant yield increase when the soil had been disced only before treatment. However, a significant yield increase was obtained with fumigation following chiseling or subsoiling.

The Effect of Soil Moisture and Air Space Content on the Efficacy of Telone.

The field in which this experiment was conducted was a Yolo sandy loam. Soil moisture and air space percentages are shown in Table 3. Triplicate randomized blocks were used. A three-month-old sugar beet crop had been disced down in the spring of 1956 in this field because of sugar beet nematode damage.

Fumigant applications were made November 28, 1956 and January 15, 1957. As a result, treatments were applied under two different soil conditions. The principal differences between the two soil conditions were soil moisture and air space content.

Treatments at both dates were applied with the field flat (unbedded) by the over-all fumigant application technique (12-inch centers).

Yields from all treatments were significantly larger than that of the untreated check (Figure 1 and Table 3). In all of the treatments applied under the soil condition with the higher air space percentage, yields were larger than those obtained with fumigation of the less porous soil at equal fumigant levels. In two of the three equal dosages, the yield differences between the two soil conditions were significant at the 5 percent level.

Figure 1.—Effect of 200 pounds (20 gallons) Telone per acre on growth in a field heavily infested with the sugar beet nematodes—untreated area to left—overall application—Santa Maria, California.

Table 3.—The Effect of Soil Moisture and Air Space Content on Efficacy of Telone in Sugar Beet Nematode Control.

Telone Dosage	Yield—Tons Sugar Beets Per Acre	
	41% Air Space (7% Water)	31% Air Space (11% Water)
10 Gallons/Acre	22.8	17.6
15 Gallons/Acre	26.1	21.7
20 Gallons/Acre	24.7	20.7
Untreated	9.0	
LSD 5%	4.3	

Comparison of Chisel and Plow Application.

This experiment was conducted at Layton, Utah, in a sandy loam field which had been fallow for one year following sugar beets. The fumigant was applied to certain plots with chisels in November, 1956, under relatively dry soil conditions (9 percent water by weight). In April, 1957, the entire field was plowed, the fumigants being applied simultaneously in the plow application plots. The spring-applied chisel treatments were then made. All applications were over-all to unbedded soil. The field was planted flat on 22-inch centers. A quadruplicate randomized block design was used.

The yield data from this experiment (Table 4) show that fall chisel application into relatively dry soil was as effective as chisel application in the spring into moist soil (15-18 percent water by weight). The latter technique is the currently accepted practice.

Yields from the spring plow-applied treatments were greater than those from their spring chisel-applied counterparts. In two out of three cases the difference between yield from equal dosages was significant at the 5 percent LSD level.

These data also support the conclusion that the nematocidal effectiveness of a technical dichloropropene-dichloropropane mixture is a function of its dichloropropene content.

Discussion

Row application has been shown previously to increase the efficiency of soil fumigants in such crops as tobacco (1)[3], tomatoes (2), and pineapples (3). The data reported in this paper show this technique is also quite effective in increasing the efficiency of Telone in the control of sugar beet nematodes. The most favorable results from bed placement were obtained with the two-shank-per-bed application.

The highest degree of nematode control is obtained near the point at which the fumigant is injected (1, 4). When this injection area coincided with the area of root growth, the most efficient control in relation to yield was obtained. In single row beets, however, it is quite probable that a single shank injection per row would be efficient, as is the commercial practice in tobacco (1).

It has been shown that soil fumigant movement is principally through the gaseous phase of the soil; therefore, increasing the quantity of air space in the soil increases the rate and distance

[3] Numbers in parentheses refer to literature cited.

Table 4.—Yield of Sugar Beets From an Experiment Comparing Fall and Spring Treatments and Plow and Chisel Applications.

			Sugar Beets—Tons/Acre		
	Gal./A.	Lbs. 1,3-D/A.[1]	Fall-Chisel	Spring-Chisel	Spring Plow
Telone[2]	12.5	115	18.5	.....	.....
	15	140	.....	19.8	.....
	20	190	.....	21.9	22.2
	25	235	21.9	20.4	24.0
Tech. mix[3]	20	130	.....	18.0	.....
	25	160	.....	19.2	23.0
	30	190	.....	19.4	.....
Untreated check				9.3	
LSD 5%				3.0	

[1] 1,3-Dichloropropene content by analysis.

[2] Contains over 90% 1,3-dichloropropenes.

[3] Technical mixture containing 1,3-dichloropropene, 1-2-dichloropropane, and other chlorinated hydrocarbons.

of fumigant movement (4, 5). Two methods of treatment under an increased air space percentage which were investigated were treatment after deep soil working (chiseling or subsoiling) and treatment of soil at about one-half of the field moisture capacity (treatment at near field capacity is generally recommended). Each of these techniques appears to have increased the efficiency of Telone (Tables 2 and 3).

In the one experiment conducted comparing plow and chisel application, the yield data showed a significantly larger yield with plow application. The more favorable response with plow application probably was due to the more complete diffusion through the soil (which was at field moisture capacity) with plow than with chisel application. Fall chisel application was intermediate between spring chisel and spring plow application in yield obtained. These observations are a further indication of the importance of sufficient air space in the soil for adequate diffusion of the fumigant. More extensive comparisons of these techniques should be made. Since these experiments were conducted on loam or lighter textured soils, no conclusions can be made concerning the influence of the techniques discussed on heavier textured soil; however, it is believed that the same principles will apply.

Although sugar analyses were run in several of the above reported experiments, no consistent differences were shown as the result of sugar beet nematode control.

Conclusions

Experiments are reported which were designed to determine the soil conditions under which the highest efficiency could be obtained with Telone in the control of the sugar beet nematode. It was found that use of the following techniques was helpful in increasing fumigant efficiency:

1. Row placement, preferably with placement directly under the future seed row.

2. Application under soil conditions favorable to diffusion; i.e., chiseling or subsoiling before treatment and treatment of soil at about one-half of the field capacity.

3. Plow application, which at equal dosages in one experiment gave somewhat larger yields than chisel application.

Acknowledgment

The author is indebted to R. N. Winters and J. Miller, Union Sugar Division, Consolidated Foods Corp., Santa Maria, California; R. Burton and C. Whitesides of the Layton Sugar Company, Layton, Utah; E. Jorgenson, Nematologist, U.S.D.A. and certain sugar beet growers in these two areas for their assistance in conducting these experiments.

Literature Cited

(1) GRAHAM, T. W. 1956. Diffusion of soil fumigants in tobacco row treatments. Phytopathology 46:13.

(2) LEAR, B. and THOMASON, I. J. 1956. Control by soil fumigation of root-knot nematodes affecting fresh fruit and canning tomatoes in California. Plant Disease Reporter 49:981-986.

(3) CARTER, WALTER. 1945. Soil treatments with special reference to fumigation with DD-mixture. Journal of Economics Entomology 38:35-44.

(4) GORING, C. A. I. and YOUNGSON, C. R. 1957. Factors influencing nematode control by ethylene dibromide in soil. Soil Science 83:377-389.

(5) HANSON, W. J. and NEX, R. W. 1953. Diffusion of ethylene dibromide. Soil Science 76:209-214.

Minutes of the Tenth General Meeting American Society of Sugar Beet Technologists

The business session of the Tenth General Meeting of the American Society of Sugar Beet Technologists was called to order by the Society's president, Mr. Austin A. Armer, at 10:30 a.m. on Tuesday, February 4, 1958, in the Ballroom of the Hotel Statler, Detroit, Michigan.

The chairman of the meeting, Mr. Armer, announced that the purpose of this meeting was to hear committee reports, the report of the secretary, the report of the treasurer, and to transact what other business as may be appropriate to this meeting.

The chairman called for the reading of the minutes of the Ninth General Meeting held in San Francisco, California, on January 31, 1956. Upon motion made, seconded, and unanimously carried, reading of the minutes was dispensed with.

The chairman asked for the report of the secretary. The secretary then read the Report of the Secretary and upon motion made, seconded and unanimously carried, the report was accepted, ordered placed on file, and made a part of these minutes.

Report of the Secretary

The membership of the Society at the close of biennium 1956-1957 was 546 individuals and companies. Members reside in 30 states of the United States and 16 foreign countries and possessions. Membership for the biennium just completed showed an increase over the previous biennium by 32 members. A list of states and countries showing the number of members in each is attached to and made a part of this report.

Membership by States and Countries—1956-57

Washington, D. C.	4	South Dakota	3
Arizona	3	Utah	49
California	143	Washington	7
Colorado	94	Wisconsin	5
Connecticut	2	Wyoming	10
Delaware	4	**Foreign Countries**	
Florida	1	Canada	40
Georgia	1	England	4
Idaho	19	Belgium	1
Illinois	15	Denmark	6
Iowa	5	Ireland	2
Kansas	2	Uruguay	1
Louisiana	1	Netherlands	3
Maryland	5	Sweden	2
Massachusetts	1	Hawaii	1
Michigan	31	Spain	2
Minnesota	8	Iran	2
Montana	14	New Zealand	1
Nebraska	12	Australia	1
New Mexico	2	Japan	1
New York	10	Germany	2
Ohio	9	Syria	1
Oklahoma	1		
Oregon	6	Total	538
Pennsylvania	1	Company Members	8
			546

Approximately 700 copies of the *Journal of the American Society of Sugar Beet Technologists* are mailed each printing. They are being sent to 36 states and 31 foreign countries. Correspondence has been conducted with an additional 10 to 15 countries, many of which are behind the iron curtain. Distribution of our Journal and research results are restricted to friendly nations in compliance with the general restrictions set forth by the United States Department of Agriculture.

The editorial and publication duties connected with the Journal have been assumed by the office of the Beet Sugar Development Foundation without cost to the Society. A delay in completing the Volume IX series has been caused by a lack of acceptable manuscripts. The Editorial (review) Board has worked diligently to keep a high standard for papers published.

The chairman then requested that the report of the treasurer be read. The treasurer thereupon reviewed receipts and disbursements during the biennium January 1, 1956 through December 31, 1957. Upon motion made, seconded, and unanimously carried, the Report of the Treasurer was accepted. ordered placed on file, and made a part of these minutes.

Balance Sheet

December 31, 1957

Cash Balance, January 1, 1956		$ 6,736.56
Publications	$ 5,672.23	2,958.88
Postage	781.46	121.04
Meeting Expense	5,518.48	434.00
Ledger Accounts	8,179.30	8,954.65
Miscellaneous	250.28	3,200.00
Membership Dues		2,885.00
Office Expenses	1,642.97	
Reprints	869.18	1,550.00
Page Overage		31.08
Regisration Fees		1,392.00
Banquet		2,610.00
Cash Balance, December 31, 1957	7,959.31	
	$30,873.21	$30,873.21

The chairman then announced that normally a report of the Resolutions Committee was read at this meeting. Since it was not possible to prepare such report in advance of the meeting, he requested that the Resolutions Committee prepare such report and that it be read at the General Session, Thursday afternoon, February 6. The secretary was instructed to include this report in the minutes of the Tenth General Meeting. The report of the Resolutions Committee is reported herewith and becomes a part of these minutes.

Report of the Resolutions Committee

BE IT, AND IT IS HEREBY RESOLVED, That the American Society of Sugar Beet Technologists extend a vote of thanks and sincere appreciation to all of those who have contributed time, talent, and energy to promoting the welfare of the Society during the past two years, particularly those individuals and agencies who have contributed so generously to the success of this, the Tenth General Meeting of the Society. Special acknowledgments are due the following: Our President, Austin Armer, for guiding the destinies of the Society during the past two years; our Secretary, James H. Fischer,

for his ever efficient service, including his professional and editorial contributions to the launching of the new Journal of the American Society of Sugar Beet Technologists and the other officers of the Society, including the members of the various committees who have contributed to the success of their meetings; The general program chairman, John O. Gaskill, and his six assistants for their efficient preparations and organization of an excellent program; the general arrangements committee composed of Grant Nichol, Loren S. Armbruster, Jack Brock, B. E. Easton, M. G. Frakes, and D. L. Sunderland for their efficient performance of the many demanding duties associated with local arrangements; Herbert Bush and his able assistance for registration of members of the Society in attendance at the meetings.

We particularly recognize the important contributions of the General Sessions speakers, Merritt Hill, General Manager of the Tractor Division of the Ford Motor Company, Dr. Paul A. Miller, Director of Extension, Michigan State University, and Dr. W. Ralph Singleton, Director of Blandy Experimental Farm and Miller Professor of Biology of the University of Virginia.

We want especially to thank the management of the Hotel Statler for the splendid handling of the convention and for the facilities and meeting rooms provided. An expression of thanks is given Silver Engineering Works for the between-session interludes complete with refreshments and conversation.

The Society appreciates and thanks the following sugar companies for their financial help and support for this Tenth meeting:

Michigan Sugar Company of Saginaw, Michigan
Buckeye Sugar Company of Ottawa, Ohio
Northern Ohio Sugar Company of Fremont, Ohio
Menominee Sugar Company of Green Bay, Wisconsin
Monitor Sugar Division of the Gage Coal Company of Bay City, Michigan
Canada and Dominion Sugar Company of Chatham, Ontario, Canada

This Society pauses in fond memory of the following departed members and friends who have passed away since the Society's last meeting:

CHARLES PETER
A. A. WRIGHT
GEOFFREY S. CHILDS
ERNST ARTSCHWAGER
JAMES R. MASON
J. T. DAVIS
PAUL T. ROBINSON
W. J. GORST
JARED B. LEWIS
A. R. NEES
H. B. WALKER
W. C. MCCARTY
ROBERT I. SMITH
S. C. GADDIE

Respectfully Submitted,

C. W. BENNETT
P. B. SMITH
FRANK RAWLINGS

February 6, 1958
Detroit, Michigan

The chairman then announced that a committee had been appointed to tally the votes cast for officers of the Society for the biennial period 1958-59. Announcement of the successful candidates was to be made during the banquet on February 5 and for the purpose of record are listed below:

President ..... H. P. H. Johnson
Vice President ..... Vernal Jensen
Secretary-Treasurer ..... James H. Fischer

ADVISORY COUNCIL

West Coast:
Russell T. Johnson
J. S. McFarlane

Intermountain:
Rowland M. Cannon
F. V. Owen

Eastern Slope:
C. E. Cormany
Andrew R. Downie
P. B. Smith

Eastern United States:
Grant E. Nichol
Perc A. Reeve

Western Canada:
Frank R. Taylor

Eastern Canada:
B. E. Easton

At Large:
C. M. Nicholson
Frank Rawlings

The chairman then announced that the meeting would accept invitations for the site of our Eleventh General Meeting. Following discussion, an invitation by Mr. Tolman, on behalf of and for Salt Lake City, Utah, was unanimously accepted as the meeting site for the Society's Eleventh General Meeting in 1960. The secretary was instructed to announce the date and meeting location following a report of such by the Local Arrangements Committee.

There being no further business, the meeting was declared adjourned at 11:45 a.m.

Forty Year Veteran Awards

George Alexander, American Crystal Sugar Company
Lyman H. Andrews, The Great Western Sugar Company
George W. Atkinson, The Great Western Sugar Company
J. R. Bachman, Amalgamated Sugar Company
Claude E. Blaney, Holly Sugar Corporation
Burnall Brown, Amalgamated Sugar Company
Julius Cabutti, Franklin County Sugar Company
DeWitt Carson, Holly Sugar Corporation
Horace W. Cole, American Crystal Sugar Company
R. H. Cottrell, Amalgamated Sugar Company
Oscar P. Dittman, The Great Western Sugar Company
Cecil W. Doherty, The Great Western Sugar Company
Paul D. Freese, Holly Sugar Corporation
Otto H. Gastler, American Crystal Sugar Company
Herbert G. Griep, American Crystal Sugar Company
Herman L. Hartburg, The Great Western Sugar Company
Herman Juergens, The Great Western Sugar Company
Edward C. Kundinger, Michigan Sugar Company
John B. McDonald, The Great Western Sugar Company
W. J. McGregor, Canada and Dominion Sugar Company Limited
Paul H. McMaster, The Great Western Sugar Company
Barrett W. Morrison, The Great Western Sugar Company
D. R. Newton, National Sugar Manufacturing Company
A. A. Norman, Spreckels Sugar Company
W. J. Rhyner, Spreckels Sugar Company
Joseph H. Trent, Franklin County Sugar Company
E. Ward, Jr., The Great Western Sugar Company
Frank Whiting, The Great Western Sugar Company
James H. Zisch, The Great Western Sugar Company

Meritorious Service Award

These awards were presented at the Ninth General Meeting to those who have been outstanding in promoting the objectives of this organization and who have been active in its affairs. The Society hereby acknowledges the important role each has played.

HARVEY E. BREWBAKER

Dr. Brewbaker was born near Bushnell, Illinois, on May 10, 1895. He graduated from the University of Illinois in 1921 and earned a Master's degree at the University of Minnesota in 1923. He was awarded a Ph.D. from the University of Minnesota in plant genetics in 1926.

While at Minnesota, Dr. Brewbaker was an Assistant in Plant Breeding, an Assistant Plant Breeder and Instructor, and an Assistant Professor. In 1930 he joined the U. S. Department of Agriculture as an Associate Agronomist with the Bureau of Plant Industry, Sugar Plant Investigations. In 1937 he became associated with Great Western Sugar Company as an Agronomist with the Experiment Station and became its Director in 1945, the position he presently holds. In 1952 he served as a Consultant for the United Nations Food and Agricultural Organization in Israel, Turkey, and Greece.

He has been most prominent in Society affairs, a charter member, and its first secretary-treasurer, a position he held for three bienniums. He became Society president in 1946 and has served at least for one biennium on every organized committee of the Society. He has, at one time or another, served as chairman of nearly all of them. His recorded service to the Society is not surpassed by any other member.

We proudly pay tribute to him with this Meritorious Service Award.

C. W. BENNETT

Dr. Bennett was born in Narrows, Kentucky, on June 8, 1895. He graduated from the University of Kentucky in 1917 and earned a Master's degree from Michigan State College in 1919. Continuing his education, he was awarded a Ph.D. from the University of Wisconsin in 1926.

Dr. Bennett has been employed by the U. S. Department of Agriculture since July 1, 1929 and, except for a special assignment in Brazil, he has devoted full time to virus diseases of sugar beets. He entered the government service as a Plant Pathologist and is presently Principal Plant Pathologist. In addition to his present duties, he is Superintendent of the U. S. Agricultural Research Station at Salinas, California.

He has been a leader in research on virus diseases of sugar beets in the western states. For his leadership and abilities, he was presented with the Superior Service Award by the U. S. Department of Agriculture in 1957. His ability to draw logical conclusions and outline solutions to problems is recognized by a large public who seeks his advice.

Dr. Bennett has been a member of the American Society of Sugar Beet Technologists since 1948. He has served on the Advisory Council, has been Chairman of the Entomology and Plant Pathology Section, has been on the Constitution and Bylaws Committee, and served on the Editorial Board for the "Journal of the American Society of Sugar Beet Technologists."

We proudly pay tribute to him with this Meritorious Service Award.

FRANK A. KEMP

Mr. Kemp was born in Nebraska and grew up in Wyoming and Colorado. A typical westerner, he is the son of pioneer parents, his father being a Wyoming cattleman and his mother born in Cheyenne, Wyoming. He received a degree in law in 1913 from the University of Colorado and spent the next decade practicing in the state and serving two years in the Army with overseas action as captain in a machine-gun battalion.

Mr. Kemp entered the legal department of The Great Western Sugar Company in 1923, became General Attorney in 1925, and was appointed Manager of two of the company's Nebraska factories the following year. He subsequently became Nebraska District Manager and Vice President of the company and was elected General Manager in 1935 and President in 1936.

As President of The Great Western Sugar Company, he has guided not only the operations of America's largest beet sugar company, but has been spokesman on many occasions for the entire beet sugar industry and also for the domestic sugar industry as a whole, both beet and cane.

In America and abroad, Frank A. Kemp of Denver is recognized as an outstanding leader of the sugar industry.

Mr. Kemp has been President of the United States Beet Sugar Association and has headed many groups within the industry. He is a Director of The First National Bank of Denver; a Trustee of the Northwestern Mutual Life Insurance Company; a Trustee of the Denver Zoological Foundation, Inc., and has been active in regional cultural historical organizations. He is an Honorary Life Member of the American Society of Sugar Beet Technologists.

We proudly pay tribute to him with this Meritorious Service Award.

RAY L. COOK

Dr. Cook began his interest in agriculture early in high school on a 120-acre farm near Michigan State University. His undergraduate studies at Michigan State were followed by graduate studies at the University of Wisconsin and a Ph.D. degree under Emil Truoc.

Dr. Cook's research in sugar beet nutrition in Michigan has been continuous for more than 30 years. He has been on the research and teaching staff of MSU since 1929. He pioneered minor nutrient studies which clearly established the economic urgency of supplying boron and manganese. His experiments involving the forcing of air through packed and non-compacted soils led to trials which proved the merit of planting beets within a day after plowing, a system known as minimum seedbed preparation adopted by over 75 percent of the Michigan growers in 1956.

He has been active in the American Society of Agronomy, has served on many of that Society's important committees, and has been equally active in the membership of the Soil Science Society of America. He is presently Head of the Soil Science Department in the College of Agriculture, Michigan State University.

Dr. Cook has been a member of the American Society of Sugar Beet Technologists since 1940 and has frequently prepared papers for the program of the Society and for publication in the Society's Proceedings and Journal.

We proudly pay tribute to him with this Meritorious Service Award.

DEWEY STEWART

Mr. Stewart was born in Eva, Alabama, on December 4, 1898. He graduated from Alabama Polytechnic Institute in 1922 and earned a Master's degree from Michigan State College in 1924. He has completed credits for the Ph.D. degree at Cornell University and the University of Maryland.

Mr. Stewart has been employed by the U. S. Department of Agriculture since June 1925 with his first assignment on research in sugar beets with headquarters at Rocky Ford, Colorado. With the exception of time spent on additional graduate study, he has been continuously connected with sugar beet research since that date.

He has made many notable contributions to sugar beet research including the production of disease-resistant varieties principally adapted to the Great Lakes region. These varieties now constitute the chief commercial material being grown in that area. He has been advanced by the U. S. Department of Agriculture to his present position as Head of the new Sugar Beet Section of the Tobacco and Sugar Crops Research Branch.

Mr. Stewart has been a member of the American Society of Sugar Beet Technologists since 1940, has served on the Constitution and Bylaws Committee and on the Awards Committee.

We proudly pay tribute to him with this Meritorious Service Award.

In Memoriam

Ernst Artschwager, Mesilla Park, New Mexico
Geoffrey S. Childs, Saginaw, Michigan
J. T. Davis, Denver, Colorado
S. C. Gaddie, West Jordan, Utah
W. J. Gorst, Worland, Wyoming
Jared B. Lewis, Nyssa, Oregon
W. C. McCarty, Windsor, Colorado
James R. Mason, Denver, Colorado
A. R. Nees, Denver, Colorado
Charles Peter, Salt Lake City, Utah
Paul T. Robinson, Chaska, Minnesota
Robert I. Smith, Saginaw, Michigan
H. B. Walker, Davis, California
A. A. Wright, Wallaceburg, Ontario, Canada